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ENGINEERING:

An Illustrated Weekly Journal.

EDITED BY WILLIAM H. MAW AND ALEX. RICHARDSON.

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VOL. CXIII.—No. 2945.] *LONDON: FRIDAY, JUNE 9, 1922.* [Registered at the General Post Office as a Newspaper.] [PRICE ... 1s. BY FOREIGN POST 1s. 4d.

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And Auxiliary Machinery as supplied to the Admiralty. 2179

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See Illustrated Advertisement Page 100, Jan. 20, 1921.

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We have a Large Stock of all standard sizes, No. 3 to 12 inclusive (15 in. to 60 in. diameter Runners), ex various Government Depts.
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See page 17, June 2. 9047

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See Advertisement page 77.

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See Advertisement, page 26. 9052

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&c. &c. 9004

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See Advertisement page 63, June 2. 3402

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9196
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See Full page Advertisement, page 43, May 26.

Matthew Paul & Co., Ltd.
Dumbarton. 9018
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See Full Page Advts., page 58, May 26.

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See Illus. Advts. last week, page 16. 9764

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See Advt. page 85, June 2
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TUTORS, 284, Oxford Road, Manchester. Estab. 1878. Enrol now for I.C.E. and I.M.E. Postal Courses. 100 per cent. passes last Exams. Reinforced Concrete—a new comprehensive course under expert engineer, £3 3s. Write for particulars. 9750

TENDERS.

METROPOLITAN WATER BOARD.

POSITIVE WATER METERS.

The Metropolitan Water Board invite

Tenders for the Supply of the

following quantities of POSITIVE METERS:—
300 ¾-in.; 100 ¾-in.; 100 1-in.; 100 1¼-in.; 50 2-in.; 50 3-in.

Forms of Tender and Specification may be obtained from the Chief Engineer, Metropolitan Water Board, New River Head, 173, Rosebery Avenue, E.C. 1, by personal application (Room 150) or upon forwarding a stamped addressed brief envelope.

Tenders enclosed in sealed envelopes addressed to the Clerk of the Board, Metropolitan Water Board, New River Head, 173, Rosebery Avenue, E.C. 1, and endorsed "Tender for Meters," must be delivered at the offices of the Board not later than Eleven a.m. on Tuesday, 20th June, 1922.

The Board do not bind themselves to accept the lowest or any Tender.

W. MOON,
Clerk of the Board.

Offices of the Board,
New River Head,
173, Rosebery Avenue, E.C. 1.
1st June, 1922. U 400

THE SOUTH INDIAN RAILWAY COMPANY, LIMITED,

are prepared to receive

Tenders for the Supply of

LOCOMOTIVE DUPLICATE PARTS, SWITCHES and CROSSINGS of 80-lb. B.H. Rails.

Specifications and Forms of Tender will be available at the Company's Offices, 91, Petty France, Westminster, S.W. 1.

Tenders addressed to the Chairman and Directors of the South Indian Railway Company, Ltd., marked "Tenders for Locomotive Duplicate Parts, or as the case may be, must be left with the undersigned not later than Twelve noon on Friday, the 23rd June, 1922.

The Directors do not bind themselves to accept the lowest or any Tender.

A charge, which will not be returned, will be made of 10/- for each copy of the specification.

Copies of the drawings may be obtained at the Office of Messrs. ROBERT WHITE & PARTNERS, Consulting Engineers to the Company, 3, Victoria Street, Westminster, S.W. 1.

A. MUIRHEAD,
Managing Director.

91, Petty France, S.W. 1.
6th June, 1922. U 434

THE GOVERNMENT OF THE BAHAMAS is prepared to receive

Tenders for the Dredging

of an ENTRANCE CHANNEL and MOORING BASIN in the Harbour of Nassau, New Providence, Bahams. Plans, Specification and Form of Tender may be obtained from the Office of the CROWN AGENTS FOR THE COLONIES, 4, Millbank, Westminster, S.W. 1, on deposit of Ten Pounds, which will be returned on receipt of a *bona fide* Tender.

Further enquiries should be addressed to Mr S. R. H. BEARD, Harbour Engineer, Nassau. The approximate net quantities to be removed are estimated at 468,000 cubic yards of limestone and corallime rock and 615,000 cubic yards of sand. The depth to be dredged over the bar is 27 ft. at low water and the range of tide does not exceed 4 ft. Tenders will be opened in Nassau on 15th July, 1922. U 305

MIDLAND GREAT WESTERN RAILWAY OF IRELAND COMPANY.

STEELWORK FOR BRIDGES.

The Directors of above Company are prepared to receive

Tenders for the Supply of

STEELWORK for Two Double line Underbridges.

Specification giving all particulars, and Drawing, can be had on application to the undersigned.

Tenders, sealed and endorsed "Tender for Steelwork," must be forwarded addressed to the Chairman, Midland Great Western Railway of Ireland Company, Broadstone Terminus, Dublin, so as to reach him not later than Monday, 19th June, 1922.

The Directors do not bind themselves to accept the lowest or any Tender.

PERCY A. HAY,
Secretary.

Broadstone Terminus, Dublin.
2nd June, 1922. U 404

VICTORIAN STATE RAILWAYS.

THE AGENT-GENERAL FOR VICTORIA, AUSTRALIA, invites

Tenders for the Supply

and DELIVERY C.I.F. Melbourne, fully inclusive of Australian Customs Duties, &c., of the following:—
CONTRACT No. 54312.

Approximately 2697 tons 80 lb. STEEL RAILS.
Approximately 2900 tons 100 lb. STEEL RAILS.
Approximately 194 tons FISHPLATES for 80 lb. Rails.
Approximately 166 tons FISHPLATES for 100 lb. Rails.

Specifications, Conditions of Contract and Forms of Tender may be obtained by *bona fide* Tenderers at the Offices of the Consulting Engineers, Messrs. JOHN COATES & Co., Ltd., Victoria House, Melbourne Place, Strand, London, W.C 2. Tenders must be delivered to the Agent-General for Victoria, Victoria House, Melbourne Place, Strand, London, W.C. 2, not later than Eleven a.m., on Wednesday, 28th June, 1922, marked "Tender for Steel Rails." A preliminary deposit of ninepence per ton must accompany each Tender.

The Government does not bind itself to accept the lowest or any Tender.

(Signed) JOHN McWHAE,
Agent-General for Victoria.

Victorian Government Office, London. U 419

GREAT SOUTHERN & WESTERN RAILWAY (IRELAND).

CONTRACTS 1922.

The Directors of the Great Southern and Western Railway Company are prepared to receive

Tenders for the Supply of the

undermentioned STORES for Three Months commencing 1st July, 1922.

	No. of Form.		No. of Form.
Acid, Sulphuric ...	30	Glass and China Sundries	27B
Asbestos Sheeting, etc.	40	Hardware (Sundry)	17
Baskets	19	India Rubber Goods	9A
Bolts, Nuts and Rivets	15	Implements, Sundry	31
Brooms and Brushes	13	Iron Tubes and Fittings	29
Brass Fittings for Carriages... ...	18	Leather	12
Do. do. for Water	26A	Locks and Keys ...	9
Do. do. for Gas ...	26B	Mats, Fibre	10
Canvas and Sacks ...	6	Nails	31
Castings, Mall. Iron	11	Packings	40
Cosch Screws and Washers	15	Plumbago	41
Corks	39	Railway Fastenings (Iron)	16
Crucibles	41	Rain Water Pipes and Gutters	25
Drysalteries	3	Ropes, Twine, & Flax	4
Emery and Glass Cloth, etc.	28	Soaps	30
Files and Tool Steel	20	Sponge Cloths ...	5
Fire Bricks and Clay	33	Signal Wire Pulleys	11
Foundry Requisites	42	Screws and Split Pins	14
Galvanized Sheets, Buckets, etc. ...	23	Tin Plates	22
Grates, Stoves and Fenders	24	Waste	5A
Grindstones	38	Wicks	5
Glass, Sheet, and Plate	27A	Wire, Fence and Signal	30A
		Wirework	30B

Forms of Tender can be obtained on PAYMENT of 1s. each from the STORES SUPERINTENDENT, GENERAL STORES DEPARTMENT, G.S. & W.R., INCHICORE, DUBLIN. Applications for forms by Post must be accompanied by Postal Order. Stamps cannot be accepted. All enquiries for information should be also directed to the Stores Superintendent.

Patterns may be inspected at the General Stores Department on and after the 9th inst., between the hours of Ten a.m. and Four p.m. (except on Saturdays).

Tenders must be enclosed in the special envelope supplied for the purpose with each schedule, and must be posted so as to be with the undersigned before Ten a.m. on Wednesday, 21st June, 1922.

The Directors will not consider any Tender unless it is furnished on the Company's Form, and do not bind themselves to accept the lowest or any Tender.

By Order,
ROBERT CRAWFORD, Secretary.

Kingsbridge Terminus, Dublin,
June, 1922. U 411

SIAM STATE RAILWAYS.

NOTICE.

Tenders are Invited for the

SUPPLY of SUPERSTRUCTURES of STEEL RAILWAY BRIDGES B.E. 2465.

Specifications and Drawings may be obtained against payment of £1 10s. from Messrs. C. P. Sandberg, 40, Grosvenor Gardens, London, S.W. 1.

Sealed Tenders, with the inscription "Tender for the supply of Superstructures of Steel Bridges B.E. 2465," must be forwarded to the undersigned, at whose office in Bangkok, Siam, they will be received up to Two p.m. on the 1st day of October, 1922, at which place and hour the Tenders will be publicly opened and read.

Right is reserved to reject any or all Tenders and to accept any Tender which, in the opinion of the undersigned, is to the interests of the Siam State Railways.

GENERAL PURACHATRA,
Commissioner-General of State Railways.

Department of State Railways,
Bangkok,
13th April, 1922. U 403

METROPOLITAN WATER BOARD.

TENDERS FOR THE SUPPLY OF STORES, &c.

The Metropolitan Water Board invite

Tenders for the Supply of

the under-mentioned STORES, VALVES, etc., for the periods of three, six or nine months, commencing 1st July, 1922, as the Board may decide:—

Tender No.
8. Iron and Steel.
10. Lead, Brass, Copper, Zinc, and Glass.
20. Screw down Stop Ferrules and Valves.
21. Sluice Valves, Bronze and W.I. Spindles.

Tenders must be made on official forms, which may be obtained from the Chief Engineer, New River Head, 173, Rosebery Avenue, E.C. 1, on and after Thursday, 25th May, by personal application (Room 150) or upon forwarding a stamped addressed brief envelope.

Applicants should refer to the number of the Tender for which forms are required.

Tenders enclosed in sealed envelopes, addressed to the "Clerk of the Board" Metropolitan Water Board, New River Head, 173, Rosebery Avenue, Clerkenwell, E.C. 1, endorsed "Tender for ....., ..." must be delivered at the offices of the Board not later than Eleven a.m., Tuesday, 13th June, 1922.

The Board do not bind themselves to accept the lowest or any Tender.

W. MOON,
Clerk of the Board.

Offices of the Board,
New River Head,
173, Rosebery Avenue, E.C. 1.
26th May, 1922. U 361

BOROUGH OF REIGATE.

The Town Council of the said Borough invites

Tenders for:—

(1) DIESEL ENGINES and SINGLH PHASH ALTERNATORS erected complete with accessories;
(2) TWO STEEL TANKS, 20 ft. diameter, for Oil Storage;
(3) A 12 ton OVERHEAD TRAVELLER, driven by single phase electric motors;
(4) ALTERATION in position of EXISTING CAST-IRON WATER TANK.

General Conditions, Specifications and Forms of Tender may be obtained from the Consulting Engineer, Mr. C. H. WORDINGHAM, C.B.E., M.Inst.C.E., 7, Victoria Street, Westminster, S.W., and 11, Mosley Street, Manchester, as follows:—

Contract No. 1, upon deposit of Three Guineas; extra copies One Guinea each;
Contracts Nos. 2, 3 and 4, upon deposits of One Guinea each; extra copies 10/6 each.

Deposits (only) will be returnable on receipt of *bona fide* Tenders.

Sealed Tenders, endorsed Tender and No. of Contract, to be addressed to the undersigned at the Municipal Buildings, Reigate, must be delivered not later than Ten a.m. on Tuesday, 27th June instant.

The Council does not bind itself to accept the lowest or any Tender.

By Order,
ALFRED SMITH,
Town Clerk.

Municipal Buildings,
Reigate.
1st June, 1922. U 402

STATE ELECTRICITY COMMISSION OF VICTORIA.

TENDERS FOR PLANT.

Tenders are Hereby

Invited for the SUPPLY, DELIVERY, etc., of the following for the Morwell Power Scheme:—

Copies of Tender Form and Specification will be available upon application to:—
AGENT-GENERAL FOR VICTORIA,
Melbourne Place,
Strand,
London, W.C. 2.

SPECIFICATION No. 243:—
ALUMINIUM STEEL CORED CABLE AND ACCESSORIES.

CHARGE:—
£3 3s. for the first two copies of Tender Form, Conditions of Contract and Specification complete. These charges will be returned on receipt of a *bona fide* tender. A third copy and any further copies will be supplied for the sum of 10s. 6d. each.

PRELIMINARY DEPOSIT:—
A Preliminary Deposit of £100 is to be lodged with Tender.

The Specification may be inspected at the above-mentioned office.

The Commission does not bind itself to accept the lowest or any tender.

Tenders may be sent by cable to the Commission to reach them by Noon, 17th June, 1922. Cable address: "Electrocom, Melbourne." Confirmatory tenders on prescribed forms may be despatched by the mail following to the undernoted:—

R. LIDDELOW, Secretary,
STATE ELECTRICITY COMMISSION OF VICTORIA,
673, Bourke Street,
MELBOURNE,
Victoria, Australia. U 407

GREAT WESTERN RAILWAY.

The Directors of this Company are prepared to receive

Tenders for the Construction

of a RAILWAY between Clydach and Pontardawe, near Swansea—total length about three miles.

Plans and Specification may be seen and Forms of Tender and Bills of Quantities obtained at the office of the Engineer, at this Station, between the hours of Ten a.m. and Four p.m.

Tenders addressed to the undersigned and marked outside "Tender for Clydach and Pontardawe Rly." will be received not later than Ten a.m. on Tuesday the 4th July next.

The Directors do not bind themselves to accept the lowest or any Tender.

A. B. BOLTER,
Secretary.

Paddington Station, London.
7th June, 1922. U 426

APPOINTMENTS OPEN.

SOKE OF PETERBOROUGH EDUCATION COMMITTEE.

Applications are Invited for

the POST of HEAD MASTER for the County Technical School, Peterborough.

Candidates must have had scientific and engineering training with teaching experience.

Salary £450 per annum, rising by annual increments of £25 to a maximum of £550 per annum.

Forms of application, which must be returned to the undermentioned not later than the 17th June, may be obtained on receipt of a stamped addressed foolscap envelope from

WALTER J. DRAGON,
Clerk to the Committee.

County Education Offices,
Peterborough.
1st June, 1922. U 396

General Manager Wanted

for the manufacture of the 11·9 Dawson Light Car. Good organiser and capable administrator required. Previous experience essential.—Apply, THE DAWSON MOTOR COMPANY, 167, Leadenhall Street, London, E.C. U 397

Manager Required for Dock

and ENGINEERING WORKS abroad. Climate excellent. White labour only employed. 1500 men engaged in docking and repairing vessels, and in Marine Engineering Shops connected therewith. Write in first instance, confidentially, stating salary, age, experience, and other particulars to X.Y.Z., c/o WATERLOW & SONS, Ltd., Great Winchester Street, E.C. U 423

Chartered Patent Agent, large

provincial city, DESIRES ASSISTANT. Must have technical and business qualifications and be able to act as Manager. Salary (commencing) £350–£500 according to qualifications. Applicants should state age and furnish particulars as to education and business experience. Good prospects for suitable man.—Address, U 415, Offices of ENGINEERING.

DERBY COUNTY ASYLUM, MICKLEOVER, Near DERBY.

The Committee of Visitors invite

Applications for the Post of

RESIDENT ENGINEER.

Candidates to have a thorough knowledge of Electric Light Installation and the general Building Trade, and able to supervise the Works Department of the Asylum.

Salary £400 per annum, with House, Coal, Gas and Garden, subject to the provisions of the Asylum Officers' Superannuation Act.

The appointment will be subject to three months notice on either side.

Applications, stating age, qualifications, and experience, with not more than three recent testimonials, must be marked "Resident Engineer," and sent in, addressed to the undersigned, not later than 17th June, 1922.

N. J. HUGHES-HALLETT,
Clerk to the Asylum Committee.

County Offices,
St. Mary's Gate, Derby.
26th May, 1922. U 393

Steam Efficiency Engineer

WANTED for a large Factory in the Argentine. The applicant must have a thorough theoretical and practical knowledge of steam and be conversant with the usual recording and measuring instruments and from the information obtained from these able to work the boiler plant efficiently and economically. One who has held a position where the economical working and scientific control of boilers and steam using apparatus was an objective preferred.—Write, stating qualifications and salary asked, giving full particulars of scientific training and practical experience. Age not to exceed 38.—"A.R.T." c/o STREETS, 30, Cornhill, London, E.C. 3. U 401

Mechanical Engineer Wanted

for repair shops (Rolling Stock) abroad. Must have had experience in maintenance of locomotives, steel wagons and general heavy machinery; also in latest shop methods and machinery. Knowledge of Spanish necessary. Age 28 to 35.—Write, stating fully experience, previous position and salary asked, to M. W., c/o DAWSON'S, 121, Cannon Street, London, E.C. U 398

Wanted, Immediately, a

thoroughly Competent and Practical ENGINEER to take full control of stone-breaking machinery and gas engine. Good wages paid and permanent position guaranteed to right man.—Address, U 395, Offices of ENGINEERING.

Wanted, Engineer as Chief

Draughtsman; must be a live man able to get production drawings out at lowest possible cost. Experience in the administration and routine of modern Drawing Offices of primary importance.—Apply, with full particulars, stating age and salary, to DRAWING OFFICE SUPERINTENDENT, THE ENGLISH ELECTRIC CO., LTD., Ordnance Works, Coventry. U 399

THE INSTITUTION OF MECHANICAL ENGINEERS.

THE Institution of Mechanical Engineers begins its summer meeting in Paris on Wednesday, the 14th inst., and on that day and the following various papers will be read and discussed; these meetings will be held in the building, 19, Rue Blanche, of the Société des Ingénieurs Civils de France. In the afternoon of these days, and on the following Friday, the 16th inst., visits are to be paid by the members to works in Paris and in the suburbs. In our issue for May 26, we commenced our account of the establishments in question by an illustrated description of the works of the Société Anonyme, Renault; in our last week's issue we gave illustrated descriptions of the works belonging to the Société Générale de Constructions Mécaniques, and of those of the French Babcock and Wilcox Company; in our present issue we are continuing the series, with illustrated articles on the André Citroën Establishments, the Works of the Nord-Paris Company, and the Levallois Works of the Hotchkiss Company. We shall complete the series in later issues.

THE ANDRÉ CITROËN ESTABLISHMENTS.

THE particular works belonging to M. André Citroën which are briefly described in the present illustrated article are those which are situated Quai de Javel, on the left bank of the River Seine, in the south-west district of Paris. They are connected to the State Railway system by several sidings, and have at their disposal a harbour or landing stage on the river opposite the works' entrance, for the supply of coal and other bulky material. The site has an area of about 30 acres, of which about 20 are covered by the various shops, offices and buildings. These are shown in the plan Fig. 1, annexed.

The works are of quite recent installation. A few months before the war, the site was chiefly occupied by a number of shops belonging to the Aciéries de France and by old tenements, the remainder being vegetable gardens. The site was acquired by Mr. Citroën in 1914, and the buildings were put down progressively but very rapidly; during the war they gave occupation to about 14,000 operatives and were actively engaged in the manufacture of 75-mm. shells which were turned out at the rate of 50,000 per day. They have been converted since the war into an admirable establishment for the construction in series of 10-h.p. motor cars, as many as 60 of these cars being built at the present time regularly day by day. We need not in the present article describe in detail the Citroën car; it is of a well-known type, and numbers of them are in service not only in Paris, but in the London streets and throughout the world.

With reference to the Citroën Javel works we may state in the first place that all the shops are roomy buildings, well lighted, ventilated, and heated during the winter months; all are one-storey buildings, an arrangement which has greatly facilitated their equipment, but some of them are provided, for greater convenience, with underground compartments containing, as the case may be, prime movers, tanks, piping or electric current mains, thus rendering the shops above entirely free for an extensive output.

The particular shops which during the great war were engaged in the manufacture of war material have maintained their general appearance, although in many instances their foundations, the piping for steam, compressed air, &c., their electric current leads, their means of access, and so forth, have been modified in order better to meet the construction of motor cars.

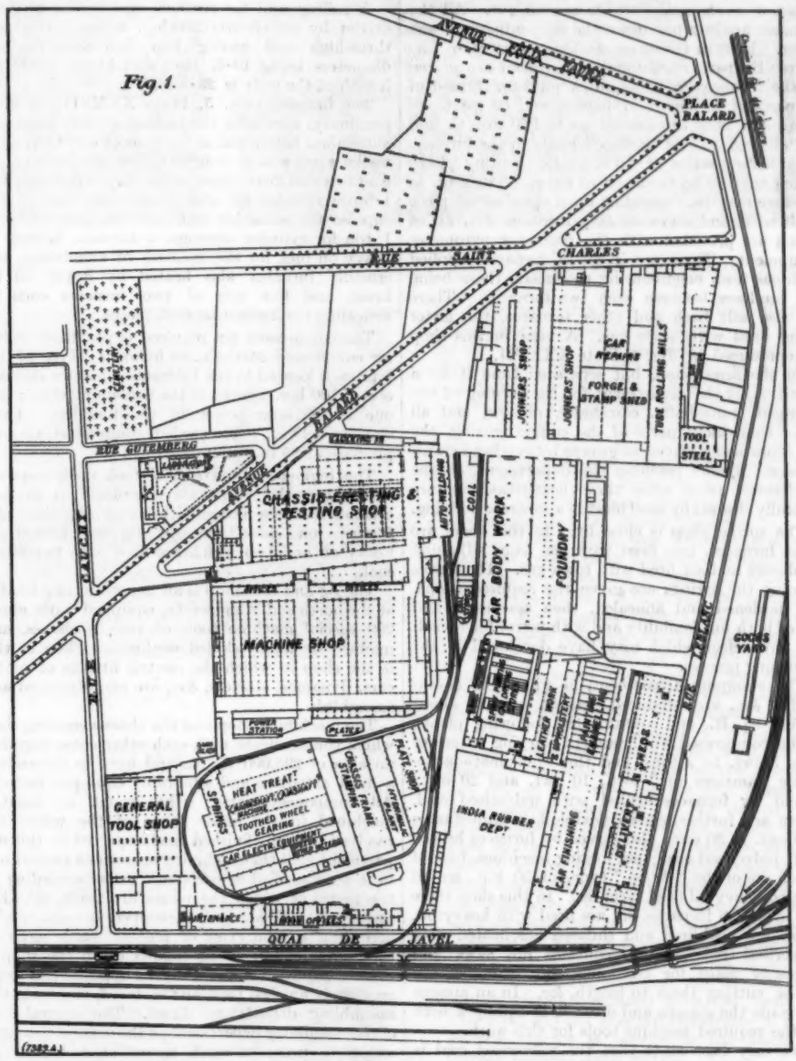
Current is supplied to the works by one of the Paris generating stations, in the form of 12,300-volt, 42-period two-phase current, over four wires; it is transformed down to 220 volts in four transformer stations in the works. The main transformer station—with an aggregate rating of 4,000 k.v.a.—contains the incoming switchboard, the transformers and the outgoing current switchboard. On the incoming side are three cables, one being a spare cable. The capacity of each cable is 3,700 k.v.a.; the two working cables deliver in parallel on bus-bars to which are connected the transformer sets and two high-tension leads for supplying the secondary transformer stations. The transformer sets in question are of 500 k.v.a., there being two single-phase transformers of 250 k.v.a., 12,300 volts to 220 volts. There are eight sets of 500 k.v.a., which deliver in parallel on secondary bus-bars, the distribution being by armoured cables having a capacity of about 200 h.p., working two in parallel, contained in a conduit and ending at the points where the current is utilised, there being 102 cables of an average length of 500 ft. Owing to the extension of the works, it was found necessary to put down subsequently three other stations supplied with high-pressure current from the main station. Of these, one is completely equipped for 2,000 k.v.a.; a second, designed for the same power, is at present equipped for 1,000 k.v.a.; whilst the third, designed for 1,000 k.v.a., is equipped for 500. A wattmeter is connected on the high-tension side of the system to register the total power used in the works, which is now 2,500 kw. The number of electric motors in service is about 1,100, their power varying from 0·3 h.p. to 250 h.p.

At this place we may conveniently deal also with the hydraulic power supply throughout the works. A hydraulic power station is equipped with 12 pumps, namely 8 double-barrelled, 2·3-in. pumps, running at a speed of 135 r.p.m. and delivering 100 gallons per minute at a pressure of 1,900 lb. per square inch, 4 treble-barrelled 3·7-in. pumps, running at a speed of 48 revolutions, and delivering over 100 gallons per minute at the same pressure. These 12 pumps, 4 of which are in constant working, are connected to two accumulators of 155 gallons capacity, having a travel of about 20 ft. and a total load of 180 tons. Two other similar accumulators are as a standby. The hydraulic plant supplies 17 hydraulic presses, there being among the larger ones 2 twin-presses, each of 320 tons for flanging the chassis frame plates; 9 single ones of 160 tons for flanging the chassis transversal members and accessory parts; and 2 of 100 tons for stamping and cutting out accessory motor-car component parts.

The coal and coke stores are practically in the centre of the works, and consist of a large quadrangular store tank, having an area of about 8,000 sq. ft. and served by normal gauge tracks and cranes equipped with automatic discharging grabs.

The shop in which the chassis frame plates and transversal members are stamped out, measures 295 ft. by 85 ft., and is equipped with flanging presses, the largest of which are the twin presses above referred to. Besides these heavier machines, there are numerous others of less power. The plate-heating furnaces are seven in number, two being fired with producer gas and five with pulverised coal. In the same shop are pressed out the rear drive casings, the brake drums and, generally, all the larger pressed work entering in the construction of the chassis. The chassis frames are riveted together at one end of the shop. This is further equipped with all the necessary shearing, punching and drilling machines for the chassis plate work, this including the chassis for all the

Fig. 1.



motor cars of 10 h.p. and 5 h.p. built by the firm. The chassis frame plate shop is illustrated in Fig. 2, on Plate XXXVII, published with the present issue.

A separate shop adjoining (Fig. 3, Plate XXXVII) is set apart for the cutting out and shaping of all lighter plate and sheet work, such, for example, as mud-guards, engine bonnets, &c., all parts required both for the chassis proper and for the car bodies. The machines are arranged in several rows down the shop and are electrically driven in groups by overhead transmission. Close to both these shops are the plate and sheet stores.

One of the numerous interesting shops in close proximity is that in which the heat-treatment of different mechanical parts is carried out. All the furnaces are in a line down the shop adjoining each other. First in the series are the cementation furnaces; the parts requiring this treatment are placed in the furnaces in boxes, in a mixture formed of 40 parts of carbonate of baryte and 60 parts of charcoal. They are heated up to 950 deg. C. and are allowed to cool down gradually in the furnace. Then follow series of furnaces for heating pieces which have to be hardened in water, oil or lead, as the case may be, depending upon the class of piece dealt with, and also annealing furnaces, &c., all of which are provided with the necessary pyrometer equipment. There are in all 14 furnaces supplied with gas from neighbouring producers, there being one producer between each two furnaces. There are also salt bath and other furnaces, the latter being fired with town gas. A view in this shop is reproduced in Fig. 4, Plate XXXVII.

In the same shop, but separated from it by a partition, is the department for the turning of the stamped crankshafts, camshafts, pinions, and all other component parts of the engine gearing, the machines being driven in groups by overhead transmission. Before reaching this department, all the mechanical parts after their heat-treatment are carefully cleaned by sand blast in a separate building.

The spring shop is close by. In this there are eight furnaces, two fired with gas from adjoining producers and six fired with town gas. The leaves forming the springs are given the required shape, are hardened and annealed, then assembled and tested both for flexibility and with petrol for revealing any defect which may have developed in the hardening process.

The stamping department, in which the crankshafts, &c., are produced, has an area of about 48,500 sq. ft., and contains the following plant: Eight compressed air hammers, varying in power from 3 cwt. to 3 tons, and three pneumatic automatic hammers of 7 cwt., 10 cwt. and 20 cwt., served by furnaces heated with pulverised coal. There are, further, eleven flexible belt drop-stamps of 6 cwt. to 30 cwt., also served by furnaces heated with pulverised coal; six forging machines, four of which are of the "Acme" type, of 50 h.p., served by two heavy oil-fired furnaces. In this shop there are in all 26 furnaces, six are fired with heavy oil, seven are coal-fired and thirteen are heated with pulverised coal. It also contains hot saws and accessory plant for trimming and grinding the pieces, cutting them to length, &c. In an annexe are made the stamps and dies; it is equipped with all the required machine tools for this work.

We may here state that the pulverised coal is distributed from a central source to all the metallurgical shops in which it is used for furnace firing. Pulverised coal is also resorted to for firing the boilers which supply steam for heating the stoves for drying the car bodies after these are painted, as stated further on. The coal is pulverised in a central shop equipped to deal with 100 tons per 24 hours, the coal used being sack of inferior quality.

The weldless steel tube and pipe shop has an area of about 50,000 sq. ft. The plant consists of machinery for rough forging the tubes by press and rolling mill, and a cold-drawing installation with annealing furnaces and pickling plant. A 250-ton press drives a hole through the billets, which are heated in three pulverised coal-fired furnaces, the billets being further drawn at the same heat under a second hydraulic press of 135 tons. The hydraulic installation has a set of pumps of 200 h.p., combined with accumulators of 145 gallons capacity. The pierced billet then passes through a rolling mill plant, consisting of a roughing mill having grooves of 5 in. down to 3 in., and a finishing mill having grooves of 3 in. down to 1·5 in. The cold-drawing installation comprises three 30-ton drawbenches, 14 similar benches of 15 tons and 4 of 5 tons, combined with the necessary machinery, cutting machines, saws, straightening machines, &c. Annealing of the tubes is carried out in two furnaces supplied with producer gas. The tubes are pickled in tanks containing a solution of sulphuric acid and water, steam-heated. The shop is served by a 5-ton overhead travelling crane from the arrival of the billets to the delivery of the finished tubes.

A rolling mill for sections and special steels is driven by an electric 200-h.p. motor; this is a three-high mill having four housings, the roll diameters being 10·6, 10·8 and 11 in., while the length of the rolls is 29·5 in.

The foundry (Fig. 5, Plate XXXVII), in close proximity, serves for the casting of iron, brass and aluminium parts, and at the time of our visit, a few weeks ago, was in course of transformation. It contains two 2-ton cupolas for engine castings, two 1·5-ton cupolas for chassis castings, two similar cupolas for malleable iron castings, one cupola of 1 ton for cylinder castings, a furnace, heated by heavy oil fuel, for the melting of aluminium, two crucible furnaces also heated by heavy oil for brass, and five sets of two furnaces ends for annealing malleable cast-iron pieces.

The compressed air required is produced in five air compressor stations, as follows: Three of 100 h.p. each located in the hydraulic pressure station; one of 100 h.p. located in the machining shop; and one of the same power in the foundry. These stations deliver, where needed, compressed air at a pressure of 85 lb. per square inch.

The high-speed and special tool steels required throughout the works are manufactured in four crucible furnaces heated with heavy oil; there are, further, one heat-treatment furnace heated by heavy oil and two which are fired with pulverised coal.

The jig and tool shop is an important one located at the north end of the works, equipped with about 200 special machine tools of various classes, and manned by highly-skilled workmen. Close to this is the shop in which the electric fittings of motor cars, dynamos, starters, &c., are manufactured and assembled.

The machining shop and the chassis erecting shop which communicate with each other cover together an area of 295,000 sq. ft., and form in themselves a most extensive and admirably equipped factory. All component parts, either rough or roughly machined in the other shops of the works are received, stored, finished and inspected in this department. All the machining operations carried out in it are classified as per series, either according to the metal of which the pieces are made, whether cast-iron, steel, aluminium, copper, bronze, or else according to the class of pieces. Each piece in the course of machining follows down the shop a natural sequence and reaches the opposite end as an accurately finished part, and is stored, or goes to the assembling department direct. The central bay of the machining department at the present time and owing to press of work serves as a temporary assembling bay for car chassis. The machine tools are mostly driven by overhead transmission, in groups, a few are separately driven, depending upon the nature of the work. Every piece is inspected after each series of operations, and when it is completely machined is finally inspected, and stamped with the date of manufacture and the initials of the work's inspector. In the centre of the building, and transversally, are series of works offices. Proceeding down the factory, on the western side, are located lockers and washstands, whilst on the eastern side are maintenance shops and a research bureau, in which new inventions and devices are given effect to and tested under service conditions on an actual motor car, to ascertain their practical value before they are embodied in the everyday manufacture of the firm. Every chassis, when fitted complete with its engine and gear, is tested separately for two continuous hours on loose rollers, which emerge just above the floor level, the back wheels resting on these loose rollers and the car engine being geared up to its various speeds. The same roller beds also serve for the brake tests, and each bed is connected to recording dials mounted on the adjoining shop pillars, for registering the working of the complete chassis at any time during the tests. Preceding this testing department, and in the same building, are a number of bays in which the engines, the change-speed gear, &c., are erected, as a whole, upon the chassis frame, and other bays in which the different mechanical component parts are assembled to form, as the case may be, the complete engine, change-speed gear, &c. As above stated, this part of the works is an admirable self-contained factory in itself, covering in all 1,300 machines of different types. We illustrate in Fig. 6, Plate XXXVIII, a series of chassis being erected, and in Fig. 7 on the same plate, a number of erected chassis ready for inspection.

The car body department comprises a wood-working shop and thin sheet-working shop, and buildings in which are carried out the painting, upholstering, varnishing and touching-up of the finished cars, covering together a total of 350,000 sq. ft. The car body framework is built up of bent wood and steel sheets, this being carried out in one and the same shop, in which the tested chassis complete enter at the eastern side and gradually follow up to the opposite end as the work upon each progresses. The shop, a view of which is reproduced in Fig. 8, Plate XXXVIII, is completely equipped with joiners' and sheet steel-working benches, each chassis having its own gang of two or three operatives, who fit body up complete as far as their own special duties are concerned, and push the chassis forward for the further stages in the body work. From this shop, the so far completed cars—which at this state of progress only lack the upholstery, hood, outside and inside car fittings—are wheeled to the paint shop where they are coated in 11 separate compartments with three coats of paint applied with the spraying device, whence they are placed in steam-heated drying stoves opposite the painting compartments. Several of the drying stoves are double, one stove being above the other, and are served by an electric lift, as shown in Fig. 9 on Plate XXXVIII.

The upholstery and leather fitting shop combined is close by, and in this the cars are finished ready for delivery after they have been varnished and touched up in every car-body detail part.

The finished cars then enter the delivery sheds, a series of well-lighted buildings, which temporarily contain the cars ready for service in France, and those for export. The delivery sheds are in direct communication with the French State Railway system by a siding.

Apart from the heat-producing plant above referred to, we may mention the heating installations which serve for manufacturing purposes and also for heating a number of shops and the offices during the winter. Five steam boilers are used for supplying steam to the stoves for drying the painted and varnished car bodies, and at the same time for heating the upholstery, finished car and other neighbouring buildings in cold weather. Another boiler supplies the steam for heating the enamelling baths, and also the enamelling shop during the winter months. Still another boiler supplies the steam for heating the tube pickling tank. There are 12 other boilers for heating the shops and offices, by low-pressure steam, or by hot water circulation in some instances. Another boiler supplies hot water to the washstands in the shops.

A car repair department, a building having an area of 60,000 sq. ft., is to the east of the works. On their arrival in this building, the cars are examined to ascertain what repairs are required, when every part is carefully listed. The cars are then washed down and take their place in a waiting garage affording accommodation for as many as 30 cars. There are several gangs of specialised operatives for dismounting and reassembling the cars, and for repairing the engines, change-speed gear, steering, &c., each part being made good again with equal care and attention to that shown in the manufacture of all new parts. Special machine tools are provided for machining any piece as needed. The department

ANDRÉ CITROËN MOTOR CARS.

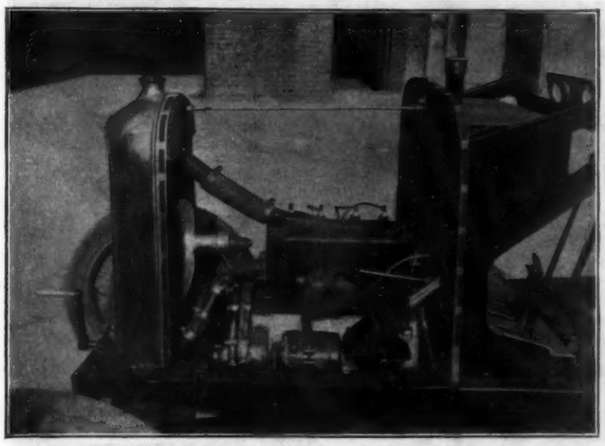


FIG. 10. 10-H.P. CITROËN CHASSIS SHOWING ENGINE.

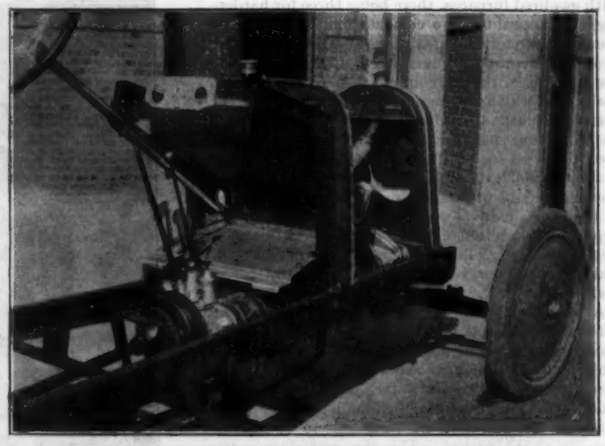


FIG. 11. 10-H.P. CITROËN CHASSIS SHOWING CONTROL GEAR.

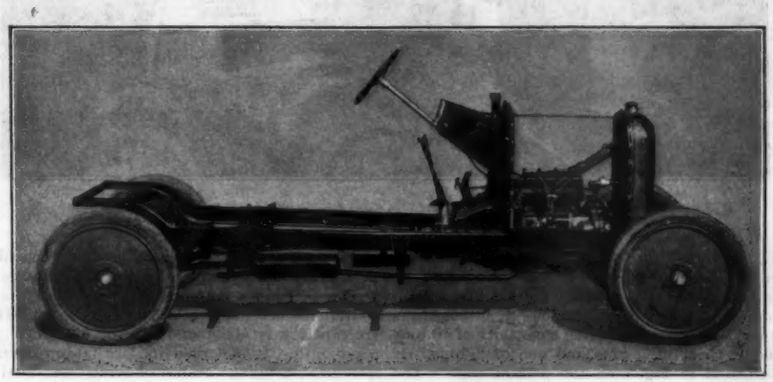


FIG. 12. 10-H.P. CITROËN CAR CHASSIS.

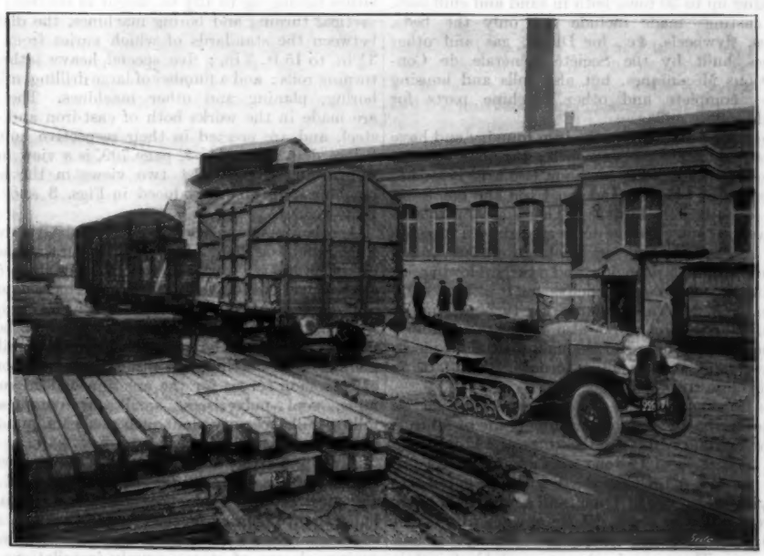


FIG. 13. THE KÉGRESSE-HINSTIN TRACTOR.

can contain 200 cars in various stages of repair, including the section set apart for renovating the car bodies which comprises a complete painting, varnishing and enamelling installation.

The transport service between the various shops throughout the works is insured by 24 electric cars, of the Elwell-Parker type; the traction motor for driving them is of 1·6 h.p., the speed 8·7 m.p.h., and the load carried 36 cwt. A movable platform forming part of the car and operated by a 0·7 h.p. motor, enables a box containing the above weight of 36 cwt. to be lifted 3 in. from the ground in 10 seconds. The cars carry Edison iron-nickel storage batteries, of 21 elements, having a capacity of 225 ampere-hours. The batteries are charged three by three in series, at 110 volts, the continuous current being supplied by a 200-kw. rotary converter.

We illustrate in Figs. 10 to 12, annexed, a 10 h.p. Citroën chassis showing the engine, the control gear and the chassis complete.

In a former article (see ENGINEERING, vol. cxi, page 234), we gave an illustrated description of the Kégresse motor car for transport in snow, built at the Citroën works. A most interesting application of this, the Kégresse-Hinstin car, fitted with an endless chain and gear similar to that we referred to in this former article, can be seen hauling in the yards of the works loaded railway wagons weighing 60 tons. One such machine, we were told, can easily haul in a straight line several wagons loaded up to 90 tons. The car is simply a 10-h.p. ordinary Citroën motor car chassis, fitted with the gear in question and with a drawbar at the rear end. It can run on any road surface and forms a most advantageous substitute for the driven capstans which were previously resorted to for the same yard service. On starting to haul an extra-heavy railway wagon, the starting effort tends to lift the front wheels of the car slightly from the ground, but these soon fall back again, the ingenious device working admirably in every way. In the car thus equipped for haulage purposes, the differential gear can be locked and unlocked at will, it contains an operated speed-reducing gear, and steering is by the endless chains combined with the front wheels. The view, Fig. 13 annexed, illustrates a Kégresse-Hinstin tractor in service in the yards of the Citroën Quai de Javel works.

Another very interesting department of the works is the laboratory which was inaugurated in June, 1917, by Mr. Léon Guillet, the well-known French metallurgist. It is most thoroughly equipped for the carrying out of chemical analyses of all the different materials used throughout the works, and for all classes of physical researches and mechanical tests; it also contains a department for micrographic investigations. Combined with the laboratory is a scientific library, and a room in which lectures are delivered periodically to members of the staff, engineers, foremen and operatives.

At the present time the Quai de Javel works of Mr. Citroën above briefly described give employment to about 6,000 operatives, of whom about 900 are women.

Besides these works, the Citroën establishments comprise works at Levallois, which occupy a site of 720,000 sq. ft., about half of which is covered by

shops and buildings. These are set apart for the present mainly for the construction of 5-h.p. cars. The machine shops contain about 600 machine tools. The heat treatment department is equipped with gas-fired furnaces, there being three for hardening and annealing, two cementation furnaces, and four separate annealing furnaces. The car-erecting shop and an annexe cover close upon 4 acres, and are supplied with the component parts of engine, gear, &c., which are assembled for fitting to the completed chassis. A brass and aluminium foundry contains four heavy oil-fired furnaces, and coke-fired furnaces for chill castings. The total power is about 1,900 h.p., divided over 120 electric motors. The method of working is similar to that followed at the Quai de Javel works, manufacture in regular sequence, inspection of each single part after each single operation, final inspection on completion, and full tests in service conditions until the car is ready for delivery.

A special forge and stamping department is at Suresnes, occupying a site of roughly 150,000 sq. ft., two-thirds of which are covered by shops, these containing 13 hammers varying in power from 3 cwt. to 30 cwt. for rough-forging machine parts, which are then finish-stamped under flexible belt stamps. There are 12 of these stamps weighing from 5 cwt. to 80 cwt. The dies and stamps are manufactured in an annexe. The department is completed by a heat treatment and grinding shops.

Saw mills and timber depots are at Issy-les Moulineaux, in communication with the Seine. Here are stocked all the classes of timber used in the various works, there being a large selection of wood-working machinery. The site has an area of about 100,000 sq. ft.

Before dealing with the construction of motor cars, Mr. Citroën put down, as reported in a former issue (see ENGINEERING, vol. xcii, page 352), gear-cutting works which, since our description in September, 1911, have been greatly extended. They now manufacture not only gearing of the largest sizes for outside works and plant, but also special gearing for the different Citroën establishments.

THE WORKS OF THE NORD-PARIS COMPANY.

THE works of the Nord-Paris Company are at Aubervilliers-La Courneuve, at a short distance from those of the Société Générale de Constructions Mécaniques and on the opposite side of the Northern of France Railway. The two works are owned by the same Board of directors, and may be said to complete each other.

The Nord-Paris establishments were started in 1873 in a small way as a smithy, by Mr. G. Sohier, who gradually developed them up to the year 1916 for the manufacture of machinery and structural ironwork. In the latter year, the needs of the war led to an enlargement of the then existing plant and to the addition of a steel works, an iron foundry and a large engineering shop. Further, dating from 1921, the Sohier establishments were given their present name, after having been taken over and reorganised with the financial aid of the Forges et Aciéries du Nord et de l'Est, the Société Générale de Constructions Mécaniques briefly described on page 680 *ante*, and the Compagnie Générale Electrique de Nancy.

The Nord-Paris works as they now stand occupy a site of about 98,000 sq. yards, of which about half is covered by various shops, offices and other buildings. They are connected with the Northern of France Railway system by several sidings, and they give employment at the present time to about 1,200 workmen.

The current for power and lighting is supplied by three transforming stations which take two-phase current at 12,000 volts, 42 periods, from the town power station (the Société d'Eclairage et de Force par l'Electricité). Two of the transforming stations, of each 350 kw., supply current for power at 220 volts and for lighting at 110 volts. The third contains a 500-kw. converter set which supplies continuous current at 220 volts for the overhead travelling cranes. The electric motors throughout the works number 300, varying in power from 2 h.p. to 165 h.p. An emergency power station contains a 200-h.p. Diesel engine coupled to a two-phase generator of 175-kw., 230 volts, 42 periods.

THE WORKS OF THE NORD-PARIS COMPANY.

FIG. 1. VIEW IN IRON FOUNDRY.

The iron foundry, a building 660 ft. in length, is equipped with a cupola having a capacity of 10 tons per hour, three of 5 tons and one of 2 tons. It is illustrated in Fig. 1 on the present page. The cupola blast is supplied by a series of blowing engines driven by 55-h.p. and 32-h.p. engines. The foundry can cast 800 tons and upwards per month, in pieces weighing up to 50 tons, both in sand and chill cast. The castings made include not only the beds, frames, flywheels, &c., for Diesel, gas and other engines built by the Société Générale de Constructions Mécaniques, but also rolls and housing frames complete and other machine parts for outside rolling mills.

The steel works adjoin the iron foundry and have a capacity of 500 tons per month; the plant consists of two cupolas of 3 tons per hour, two acid Bessemer converters of 1·5 tons, and one 1 ton and one 8-ton basic open-hearth furnace. There are two blast engines; a rotary blower delivering air at a pressure of 50 cm. height of mercury column, at 500 r.p.m., driven by an 85-h.p. engine, and a turbo-blowing set, drawing 90 cub. m. of air, delivering it at a pressure of 5 m. height of water column, the turbine being of 165 h.p. The steel works also comprise a number of moulding machines for the manufacture of pieces in series and an annealing furnace. The fettling shop is close to the cupolas.

The iron foundry and the steel works are served by one overhead electric travelling crane of 50 tons with an auxiliary 10-ton crab; three of 15 tons; one of 12 tons; two of 12 tons with an auxiliary 4-ton crab; one of 5 tons provided with an automatic emptying grab; two of 4 tons, and a number of other cranes of different types. A compressed air station supplies the necessary air to fettling apparatus and hammers. There are, further, a sand blast installation and an electric and oxy-acetylene welding apparatus. The pattern shop is common to both the iron foundry and the steel works. It measures 165 ft. by 130 ft., is in three bays and contains a complete series of wood-working machinery.

The heavy engineering shop is in a line with the foundry and steel works, and is in indirect communication with the fettling stations. The machinery with which it is equipped can deal with the heaviest castings, such, for example, as flywheels up to about 40 ft. in diameter and pieces weighing up to 100 tons. Its capacity is about 400 tons of machined parts per month. It is served by two 50-ton overhead electric travelling cranes having an auxiliary 10-ton crab, a similar crane of 15 tons, one of 8 tons and two others of 5 tons each. Among the larger machine tools may be mentioned six face-lathes having up to 19¾ in. height of centres; four vertical turning and boring machines, the distance between the standards of which varies from 4 ft. 3¼ in. to 15 ft. 3 in.; five special heavy lathes for turning rolls; and a number of large drilling, milling, boring, planing and other machines. The rolls are made in the works both of cast-iron and cast-steel, and are erected in their respective housings before delivery. Fig. 2, page 709, is a view in the roll-turning shop, whilst two views in the heavy machine shop are reproduced in Figs. 3 and 4 on Plate XXXIX.

Another machine shop, shown in the two views Figs. 5 and 6 on Plate XL, is set apart for the machining of all lighter work; it is served by three 5-ton electric overhead travelling cranes. It has a capacity of production of 200 tons per month. It is equipped with 30 lathes, six vertical turning and boring machines, besides a large number of drilling, milling, planing, gear-cutting and other tools. A portion of this shop serves for the erection of lead rolling mills, coal pulverisers, small air compressors, rolling-mill accessory plant such as shears, punching machines, &c.

A shop for the manufacture of rolling-stock is close by and is equipped for the machining of iron and steel castings and other pieces entering in the building of wagons. At the present time this shop is set apart for the assembling of superheaters for various classes of steam supply installations, the construction of agricultural tractors, &c. A smithy contains a 10-cwt. hammer driven by compressed air, and two flexible belt drop-stamps of 10 cwt. and 4 cwt. respectively.

At Le Bourget, a distance of about 2 miles from the Nord-Paris works is located a structural plant, completely equipped for the building of all classes

THE WORKS OF THE NORD-PARIS COMPANY.

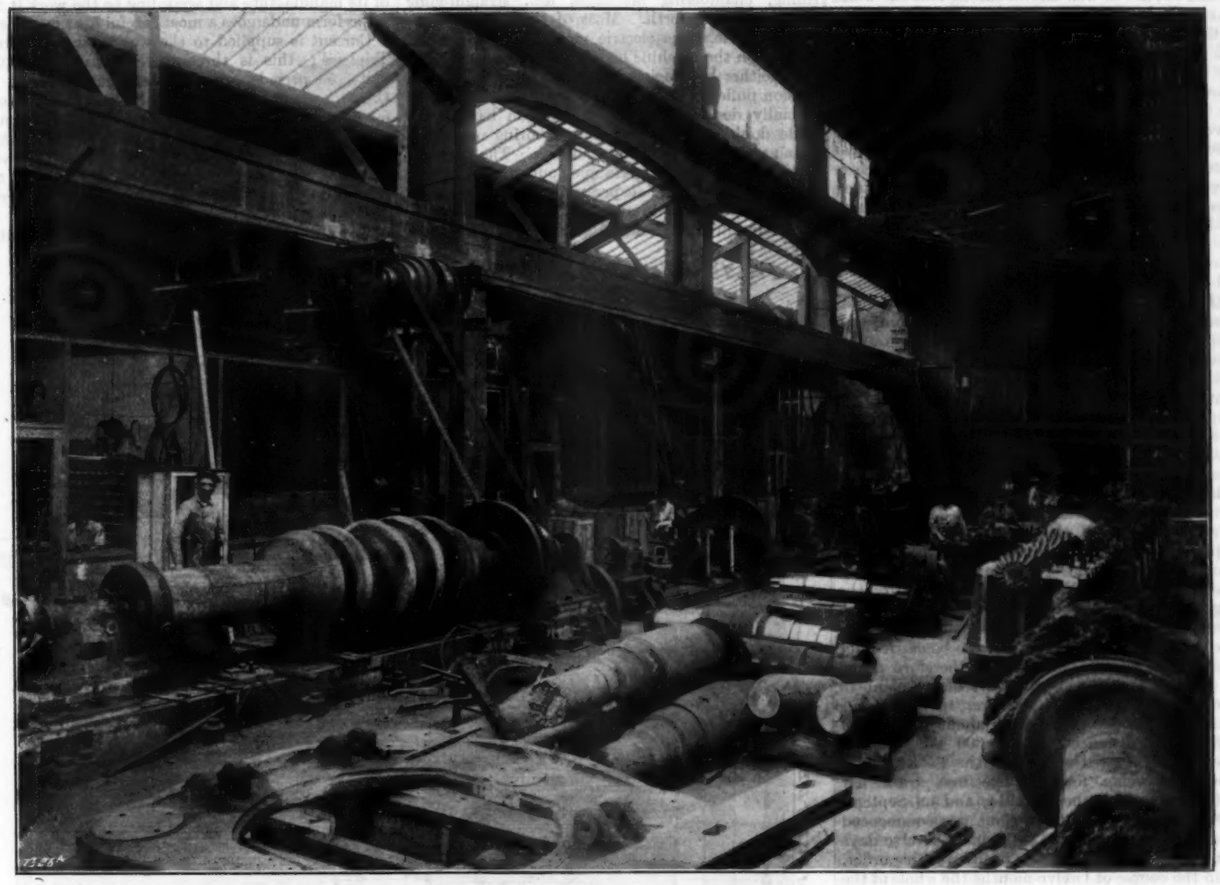


FIG. 2. VIEW IN ROLL-TURNING SHOP.

of steel structures, including bridges, the framework of overhead travelling cranes, pit gear, &c.

The various departments are completed by a laboratory for chemical analyses and physical tests.

An apprentice school gives practical instruction to as many as 80 boys at a time; it is under the charge of the different foremen, and on leaving the school, the boys are distributed among the various shops to continue their experience in the different crafts for which they are found to be suited.

PATENT OFFICE METHODS.

CONSIDERABLE discussion has arisen lately in several quarters as to the delay occasioned in obtaining the grant of Letters Patent. There is no doubt that this exists, and there are several reasons to account for it. In the first place the Patents and Designs Act of 1919 increased the time within which complete specifications might be lodged after provisional specifications had been filed from six months to nine months with a possible extension of a further month on payment of fees. Although this should not affect the time taken by examiners in giving the results of their official searches it nevertheless usually increases the time taken for the grant of a patent because inventors often take advantage of the longer period allowed for filing their complete specifications. Some are not aware that this is unnecessary, and if desired they may file a complete specification at any time after the provisional has been lodged provided it is deposited within the period named. An inventor often has his invention thoroughly worked out at the provisional stage, but in order to secure an early date he does not wish to delay matters, for the preparation of what may be elaborate drawings. Under these circumstances he would be well advised to file a provisional specification, and then begin at once the preparation of his drawings and complete specification, lodging the necessary documents at the Patent Office as soon as they are ready. In practice, examiners deal with applications as regards making the search as far as they possibly can in the order in which they are received, but unquestionably variations take place when many applications are outstanding near the date of acceptance. It is certainly found that these are given precedence, perhaps because if this were not done, an application might very well be allowed to lapse or have to be post-dated, with the attendant disadvantage that someone might have arrived at the same invention at a date between the filing of the provisional specification and the date given on post-dating. The number of applications lodged in the Patent Office has materially increased in recent years, whilst the war necessarily had the effect of decreasing the examining staff. It is likely that the reduced staff will be increased in the near future.

The applications for the past nine years progressively increase from the year 1915, a large drop being occasioned when war was declared in 1914. The actual numbers are as follows:—

1913	30,102
1914	24,847
1915	18,225
1916	18,686
1917	19,358
1918	21,933
1919	32,892
1920	36,680
1921	35,163

Applications lodged during the present year when plotted against time seem to show that a further record is likely to be established, although one cannot predict at this early stage, particularly as during the past two years a large influx of foreign specifications occurred.

The United States Patent Office is also finding difficulty in dealing with patent matters, it being shown by the Commissioner in his last official report that at the present time an application is not normally reached by an examiner until ten months after it has been filed. On the other hand, if special circumstances are shown, an application may be examined and the whole procedure settled within a month. Special treatment of this kind is evidently one of the reasons why ordinary applications are delayed. On the other hand the United States Patent Office has to deal with very many more cases than the British Patent Office. The total number of patent applications, including patents, designs and re-issues in 1921 amounted to 93,328. This included 87,408 applications relating to inventions, and of these or previous applications 48,536 were allowed last year. It was reckoned by the Commissioner that at the end of 1921 his department were 61,000 applications in arrear.

Notwithstanding all this there does still remain the fact that at the present time the British Patent Office do not, for some reason, issue an official letter giving the results of a search on a complete specification until a very much longer period than occurred before the war, even three or more months, and many patentees and others interested regard the pre-war practice as being decidedly preferable.

THE LEVALLOIS WORKS OF THE HOTCHKISS COMPANY.

THE Hotchkiss Company and the work it has carried out are so well known throughout the world that a very brief introduction to our description of their artillery establishment at Levallois-Perret will suffice. The origin of the concern dates from the Franco-Prussian war of 1870-71, when the American engineer, B.-B. Hotchkiss put down in the South of France, at the request of the French Government, a plant for the manufacture of war material. This plant, a few years later, he transported to St. Denis, to the north and in close proximity to Paris, where it still exists after having been developed in succeeding years. It is at these St. Denis works that were built for many years the revolver-guns, quick-firing and other guns which have rendered the name of Hotchkiss a well-known one among the armies of many nations. At the death of Mr. Hotchkiss, in 1885, the business passed into the possession of the present company, which, in 1896, commenced the design of an automatic machine-gun; this, shortly after, was adopted by the French Army, together with a similar one manufactured in the French arsenals. Later, the company undertook, and continues, the building at its St. Denis works of other specialties, among which may be mentioned motor cars of different types. When the great war was declared on a world at peace by Germany, in 1914, the French Government immediately applied to the company to rapidly increase the number of quick-firing weapons in the French Army. The time and the circumstances were most critical, and the apprehensions entertained with reference to the dangerous situation of the St. Denis works, which the course of events soon justified, rendered it very difficult for effective manufacture to be carried out there. The French Government therefore asked the company to transport a part of its plant to Lyons, a very difficult problem, involving the shifting of over 400 persons and about 400 tons of machinery a distance of over 300 miles. This, however, was carried out whilst the Battle of the Marne was being fought. The first train left St. Denis on September 3, 1914, and on September 8, the re-erecting of the plant was commenced in the works of Mr. Pilain, in Lyons. Twelve days after, the re-erected plant was in full working order, and in the course of twelve-months the whole of the Pilain establishment was manufacturing automatic machine-guns. In the meantime, the St. Denis works were regaining their full activity. The Pilain works, for their part, gradually increased their production in great proportions as the war proceeded. The activity displayed by the Coventry establishments on the same lines is well-known to our readers.

The Hotchkiss works at Levallois, which form the subject of out present review, were commenced during the war by Messrs. Clerget Blin & Co., for the construction of the Clerget aeroplane engines. They were acquired, re-equipped and enlarged by the Hotchkiss Company specially for the construction of automatic machine-guns, of the heavier and lighter types and the repeating rifle. They are illustrated in elevation and plan in Figs. 1 and 2. The equipment of the works is so complete that the company is able to set apart several of its very special machine tools for the manufacture for outside firms of a number of intricate pieces of machinery, but its main activities are brought into play for the construction of the Hotchkiss guns and repeating rifles of different types. A new Hotchkiss repeating rifle, to which reference is made further on, is illustrated in Fig. 3, page 711.

The Levallois works comprise on the ground floor and in direct communication with the main offices an admirable shop, views of which are reproduced in Figs. 5 and 6 on page 720. This shop is covered by a saw-tooth roof, is most adequately lighted in every part of its area, and the effect it creates upon a visitor upon entering it from the main offices is most striking. In it are machined all the principal component parts of the three types of arms above referred to, the barrels, breech pieces, recuperator pistons, and so forth. It contains a most complete series of modern lathes, milling machines, both automatic and semi-automatic, surface grinding machines, slotting machines, drilling and other machines, also complete sets of machine tools specially designed for the manufacture of artillery, such as rifling, chambering machines, &c., straightening presses and so forth. Most of the machines are driven by separate electric motors on the ground level or on the machine bedplate, the machine drive being either by gearing or by belt provided with a tension pulley. Those on the east side of the shop, specially designed for machining gun barrels, include double-spindle drilling and boring machines, rifling and other machines complete. The metallic cartridge-feed strips are stamped out of steel sheets, and shaped in special presses. They are then heated and hardened individually, the heating furnace being fired with town gas; then follows their annealing in a neighbouring furnace also fired with town gas, the strips in this latter furnace being placed side by side on a kind of chain conveyor which travels slowly through the furnace. Both furnaces are equipped with pyrometer sets, the annealing furnace having three distributed over its length. The feed strips are then cleaned and polished by hand brushes.

In the ground floor machine shop, and partitioned off, is the general tool stores containing besides the different tools, all jigs and gauges, carefully classified according to the work for which they are destined. Each operator is provided with these at his request and against a receipt. There is, further, a works' inspection department, whose duty it is to thoroughly inspect and to pass every single piece as it undergoes the different processes of manufacture and when completely machined. All pieces concerning which the least doubt is entertained are placed apart day by day, and these are inspected by the works manager who finally decides concerning them. There is a stores in which the various gun component parts are classified after each single machining operation performed upon them, and another stores in which they are kept when completely machined until wanted for the assembling of the gun. Every piece in the course of its manufacture and according to the work it has to perform undergoes a most careful heat treatment.

Current is supplied to the works by the Secteur Triphasé; this is three-phase current at 10,000 volts, 50 periods, which is transformed down by the company to 200 volts for power and 110 volts for lighting. In case of an emergency, a portion of the required current would be generated in a 300-h.p. Diesel engine set, direct coupled to a 220-volt machine, and located in the machine shop on the ground floor. This current generating set is shown in Fig. 4.

The jig and tool-designing room, the costing offices, those in which diagrams are prepared for following up every single operation and keeping record of the progress of the work in the different gangs, also communicate with the machinery shop of the ground floor.

To the north and facing the River Seine are the main offices built, as are the whole works, of iron framing and concrete.

As will be seen from Figs. 1 and 2, there are three floors above a portion of the establishment. Access is had to these by double stairways and lifts for the staff and for machinery. For the purpose of our brief description of this part of the works, we may conveniently take the various departments they contain in the following order:—

The series above the partitioned-off tool stores on the ground floor machine shop comprises, on the first floor, lockers with washstands, the operatives clocking in on entering the shop. In this women only are employed, being engaged in this particular instance on semi-automatic machine tools for making rear sight-leaves, sight-slides, sight-bases, strikers, extractors, &c. The machine tools are driven

Fig. 1. LONGITUDINAL SECTION A.B.

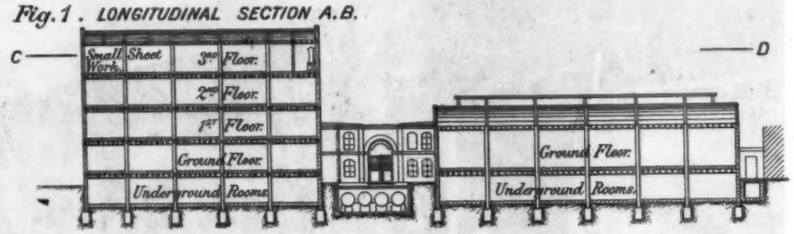
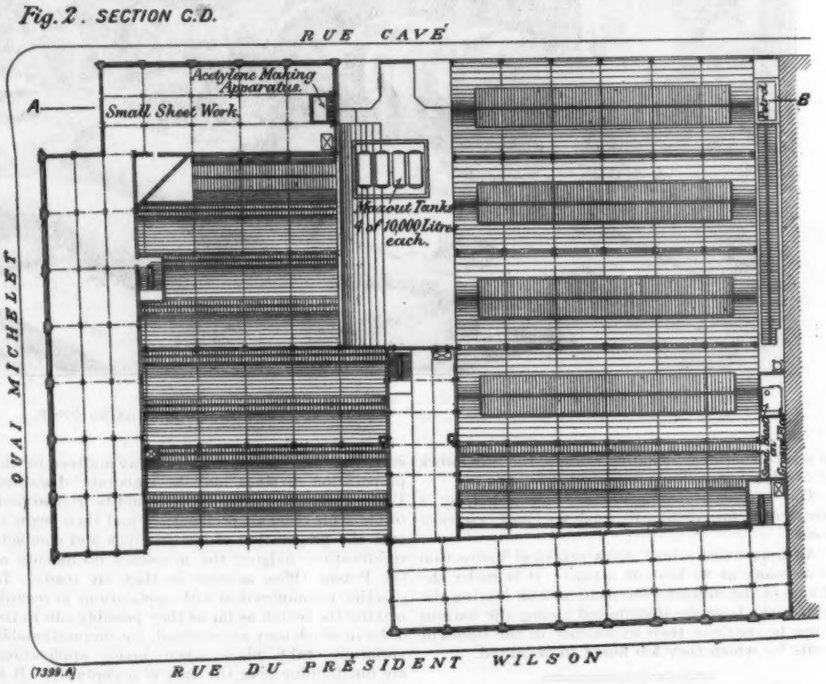


Fig. 2. SECTION C.D.



THE LEVALLOIS WORKS OF THE HOTCHKISS COMPANY.

FIG. 3. THE HOTCHKISS LATEST AUTOMATIC REPEATING RIFLE.

FIG. 4. CURRENT GENERATING SET DRIVEN BY 300-H.P. DIESEL ENGINE.

by overhead transmission, except for a number which are driven by a separate motor carried on the machine base plate. In a separate room are the buffing machines, disc wheels, brushes, &c., driven by overhead transmission, all these machines being fitted with suction hoods for evacuating all dust particles. On the second floor, the arrangement at the entrance is the same as on the first, and the department is equipped with special machine tools for rifle detail parts, for making stands for the automatic machine guns, also for the erecting of small donkey feed pumps and Westinghouse air brakes for outside firms. The entrance on the third floor is symmetrical with those below, and the shop is set apart for the manufacture of jigs, calipers, special milling cutters and drills required throughout the works.

The two series of floors which are above the main offices and above those machine tools which, on the ground floor, are in close proximity to the Diesel engine current-generating set, communicate with each other. Taking these together, they comprise on the first floor the general drawing office, blue print room, and a research department for carrying out trials of new devices so as not to interfere with the machining and erecting work in progress. On the second floor are a whole series of machines for the manufacture of small detail parts, such as front-sight rings, feed guides, breech pieces, followers, breech-covers, &c., including milling, grinding and other special machines, supplied with the necessary tools from an adjoining stores. On the third floor, the fitting and assembling of the automatic machine-gun is carried out. The browning of all gun parts takes place in a separate room on this same floor; it contains the necessary acid and other tanks, baths, and steam heated ovens, a well-known process which prevents the parts from rusting in service. Near this is a maintenance sheet and tin-plate shop.

Access is had to the underground compartments by a separate entrance, inside which is a weigh-bridge. These compartments form stores for steel bars, oil, petrol, the heavy mineral oil being stored in four tanks, shown in Figs. 1 and 2. They also contain the boilers for heating the shops and offices by low pressure steam during the winter months; a rifle range of 170 ft. in length for the firing of arms during speed and pressure tests, and the lockers and washstands for the men who work in the ground floor machine shop. The underground compartments are continued under the street in front of the offices by coal depots into which coal is delivered direct.

Close to this separate entrance is the infirmary fully equipped for first aid in the event of accidents to the operatives. A canteen is also provided, in which the operatives can take their meals.

The new repeating rifle which has recently been brought out by the Hotchkiss Company is illustrated in Fig. 3 above referred to; it weighs 16·5 lb. As will be seen, it is supported in front on two small sledge-shaped pieces which, when the rifle is not in use, turn back against the barrel. This is a special feature of the new weapon, and a distinct improvement upon the front support consisting of two pointed bars which deeply enter the ground; the Hotchkiss rifle slides on the two sledge-shaped front supports, which follow every movement of the rifle, insuring a greater precision in the firing. The displacement of the rifle in actual use is at all times parallel with the ground, and there is at no time any angular displacement. It fires metallic cartridge-feed strips containing each 15 cartridges, a number of such charged strips being easily carried by the men. The feed strips are inserted on the right-hand side of the rifle, the ejection of the empty cartridge cases taking place underneath, so that the neighbouring men are in no way interfered with by them. The working of the rifle is similar to that of all the Hotchkiss guns; a gas passage is at the middle of the barrel, the gas acting upon a follower which is connected to the closing mechanism.

The travel of the cartridge-feed strip is governed by a special mechanism placed above the rifle, this being the mechanism which is contained in a box that encloses the whole of the upper part of the rifle at this part of its length. Access is had to the inside of the gun by removing a cartridge support, i.e., the feed-guide, or feed-hopper, which allows the whole feed strip to be removed, in case of jamming, for example. The rifle can be taken to pieces and reassembled without the aid of any tool; the whole mechanism is of the simplest kind of its sort and has been designed so that every stress is transmitted exactly along the axis of the barrel. The whole closing device is built so as to insure absolute safety, a curved piece forming part of the breech mechanism preventing the firing of the rifle until the breech piece is completely closed. The rifle is fitted with a mechanism for governing the speed of firing.

During the war, it often happened that the men fired at an exaggerated speed, and in order to prevent this, and to secure a maximum effect, certain mechanism has been embodied in this new weapon. The rifle is cocked mechanically on the discharge of each separate round, when the follower acts upon a lever, this allowing the raising of a catch which secures the closing device on its return. The catch can only be lowered after a determined time, the duration of which is governed by the oscillation of a "vibrator" having a rocking-lever action. The cadence can thus be regulated, according to the dimensions and the weight of the "vibrator" fitted, and the gun be made to fire from 200 to 600 rounds per minute, the latter being the maximum firing speed of this particular gun. The gun can be regulated for any given firing speed. As is the case generally with the Hotchkiss weapons, it can fire shot by shot, or can magazine-fire, and is provided with a safety lock. The pressure of the powder gases can be regulated by a simple cylindrical shaped piece; this allows the placing opposite the gas passage of the barrel of a smaller or larger hole cut in the cylindrical piece in question, according as greater or less pressure is required. Firing is regulated by this cylindrical piece; it is made for the purpose with holes of different sizes, each of which can be brought to face the passage in the barrel.

A further interesting detail is that each steel cartridge-feed strip containing its 15 live cartridges weighs less than the empty spring curved metallic self-loader. As above stated, the empty cartridge cases are ejected below the gun; the empty feed strips are ejected at the side.

The Hotchkiss machine guns which were extensively used during the war are well-known, and need no further comment. We may remind our readers that in a preceding issue (see page 401 *ante*) we published an illustrated description of the Hotchkiss-Taylor system of tangent rack gearing manufactured at the Coventry works.

THE EFFICIENCY OF THE HAMMER BLOW, AND ITS EFFECTS WITH REFERENCE TO PILING.

By A. HILEY, M.I.N.A., Assoc.M.Inst.C.E.

(*Continued from page* 674.)

In dealing further with the determination of efficiencies which account for the losses taking place above the pile head and in the steel tube in particular, Tables III, IV, V and VI have been extended to include for effective heights of fall of W

amounting, within limits given by steam hammers, to 25 in., 50 in. and 75 in.

The loss of efficiency in the tube,

$$\eta_3 = \frac{P}{W} \cdot \frac{1}{2A_d} \cdot \frac{p^2}{E} \cdot \left(\frac{A_0}{A}\right)^2$$

has been tabulated for the ratios of $\frac{P}{W}$ stated.

The concomitant loss shown by η_1 is also set down and is compatible with evidence associated with losses of the nature occurring at the locality of impact, the quantitative values given throughout each table, which are distinguished by the figures selected for p, are identical with the values for η_3, as calculated by the above formula for the condition where $\frac{P}{W} = \frac{1}{2}$.

The range of values chosen for p in Tables III to VI extend from 500 lb. per square inch to 2,000 lb. per square inch, which includes the average working conditions of between 1,000 lb. and 1,500 lb. per square inch, representing a resistance R encountered of between 108 tons and 162 tons for the actual size of pile dealt with.

On the sufficiency of the resistance R principally depends the safety of the structure erected later on the pile foundation, and it becomes desirable during most piling operations to be able to form a close estimate of the actual resistance occurring, so that on the one hand the finished pile may safely take its maximum load without settlement, and on the other that further effort need not be unnecessarily prolonged.

An index to this information is afforded by the measurement of the set s in conjunction with the curves as calculated and set out in diagrammatic form touching on the various elements involved, as shown in Fig. 7, page 713.

Fig.2. CURVES OF EFFICIENCIES FOR VALUE OF p-500 LBS. PER SQ. IN.

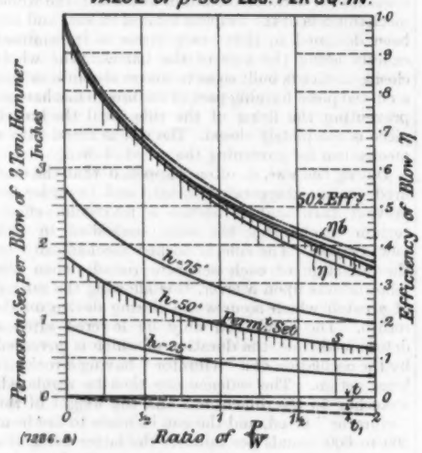


Fig.3. CURVES OF EFFICIENCIES FOR VALUE OF p-1,000 LBS. PER SQ. IN.

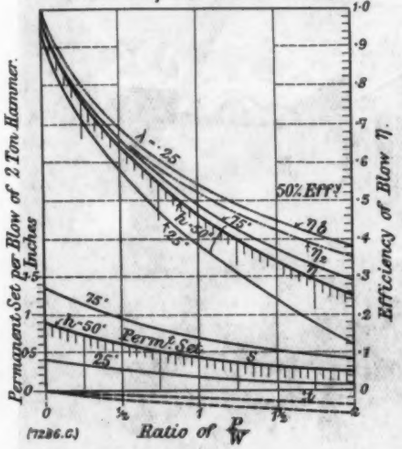
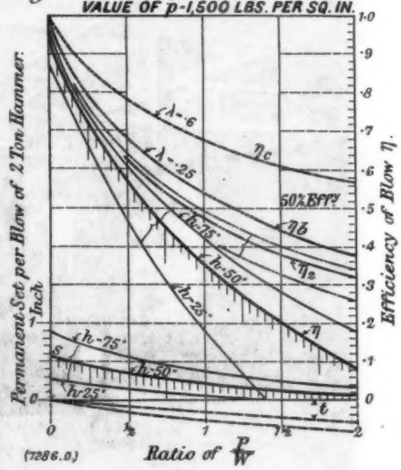


Fig.4. CURVES OF EFFICIENCIES FOR VALUE OF p-1,500 LBS. PER SQ. IN.



TABLES III TO VI.—*Efficiency of Blow as Transmitted to Head of Tube and as Usefully available at the Pile Shoe.*

TABLE III—*Case I.*—Where p = 500 lb. per sq. in. pressure below shoe.
∴ R = 54 tons.

Ratio of $\frac{P}{W}$	η_0	Height of Fall.	Correction for η_1	η_2 Efficiency at Head of Tube $\eta_0 - \eta_1$	Correction for Pile Tube Efficiency η_3	Overall Efficiency η Available at Pile Shoe $= \eta_2 - \eta_3$
		in.				
0	1·0	25	0·013	0·987	0·0	0·987
		50	0·007	0·993	0·0	0·993
		75	0·005	0·995	0·0	0·995
½	0·687	25	0·013	0·674	0·013	0·661
		50	0·007	0·680	0·007	0·673
		70	0·005	0·682	0·005	0·677
1	0·531	25	0·013	0·518	0·026	0·492
		50	0·007	0·524	0·013	0·511
		75	0·005	0·526	0·009	0·517
1½	0·438	25	0·013	0·424	0·039	0·385
		50	0·007	0·431	0·019	0·412
		75	0·005	0·432	0·013	0·419
2	0·375	25	0·013	0·362	0·052	0·310
		50	0·007	0·368	0·026	0·342
		75	0·005	0·370	0·020	0·350

TABLE IV—*Case II.*—Where p = 1,000 lb. per sq. in., or R = 108 tons.

Ratio of $\frac{P}{W}$	η_0	Height of Fall.	Correction for η_1	η_2 Efficiency at Head of Tube $\eta_0 - \eta_1$	Correction for Pile Tube Efficiency η_3	Overall Efficiency η Available at Pile Shoe $= \eta_2 - \eta_3$
		in.				
0	1·0	25	0·052	0·948	0·0	0·948
		50	0·026	0·974	0·0	0·974
		75	0·017	0·983	0·0	0·983
½	0·687	25	0·052	0·635	0·052	0·583
		50	0·026	0·661	0·026	0·635
		75	0·017	0·670	0·017	0·653
1	0·531	25	0·052	0·479	0·105	0·374
		50	0·026	0·505	0·052	0·453
		75	0·017	0·514	0·035	0·479
1½	0·438	25	0·052	0·386	0·157	0·229
		50	0·026	0·412	0·078	0·334
		75	0·017	0·421	0·052	0·369
2	0·375	25	0·052	0·323	0·210	0·113
		50	0·026	0·349	0·105	0·244
		75	0·017	0·358	0·070	0·288

TABLE V—*Case III.*—Where p = 1,500 lb. per sq. in. pressure below shoe.
∴ R = 162 tons.

Ratio of $\frac{P}{W}$	η_0	Height of Fall.	Correction for η_1	η_2 Efficiency at Head of Tube $\eta_0 - \eta_1$	Correction for Pile Tube Efficiency η_3	Overall Efficiency η Available at Pile Shoe $\eta_2 - \eta_3$.
		in.				
0	1·0	25	0·12	0·88	0·0	0·88
		50	0·06	0·94	0·0	0·94
		75	0·04	0·96	0·0	0·96
½	0·687	25	0·12	0·567	0·12	0·447
		50	0·06	0·627	0·06	0·567
		75	0·04	0·647	0·04	0·607
1	0·531	25	0·12	0·411	0·24	0·171
		50	0·06	0·471	0·12	0·351
		75	0·04	0·491	0·08	0·411
1½	0·438	25	0·12	0·318	0·36	−0·042
		50	0·06	0·378	0·18	0·198
		75	0·04	0·398	0·12	0·278
2	0·375	25	0·12	0·255	0·48	−0·225
		50	0·06	0·315	0·24	0·075
		75	0·04	0·335	0·16	0·175

For piles of this class which are formed by the subsequent depositing of concrete in the cavity provided, it will be obvious, especially for long piles, that a considerable accession to the bearing power will ultimately be afforded by the frictional contact between the sides of the pile and the ground.

If allowance be made for this corresponding to the nature of the resistances known to have been passed through during driving, and added to the value of R as ascertained, the latter should be satisfactory if there results a factor of safety of 4 over the working load.

If a further estimate of the value of R reached during the last stage of driving be sought for, its computation would involve, in addition to the measurement of the permanent set s, an accurate calibration of the temporary compression set t, as well as a reasonably close estimate of the overall efficiency η wherewith to furnish the value of the useful energy.

TABLE VI—*Case IV.*—Where p = 2,000 lb. per sq. in. pressure below shoe.
∴ R = 216 tons.

Ratio of $\frac{P}{W}$	η_0	Height of Fall	Correction for η_1	η_2 Efficiency at Head of Tube $\eta_0 - \eta_1$	Correction for Pile Tube Efficiency η_3	Overall Efficiency η Available at Pile Shoe $\eta_2 - \eta_3$
		in.				
0	1·0	25	0·21	0·79	0·0	0·79
		50	0·105	0·895	0·0	0·895
		75	0·07	0·93	0·0	0·93
½	0·687	25	0·21	0·477	0·21	0·267
		50	0·105	0·582	0·105	0·477
		75	0·07	0·617	0·07	0·547
1	0·531	25	0·21	0·321	0·42	−0·099
		50	0·105	0·426	0·21	0·216
		75	0·07	0·461	0·14	0·321
1½	0·438	25	0·21	0·228	0·63	−0·402
		50	0·105	0·333	0·315	0·018
		75	0·07	0·368	0·21	0·158
2	0·375	25	0·21	0·165	0·84	−0·675
		50	0·105	0·270	0·42	−0·150
		75	0·07	0·305	0·28	0·025

General Pile-Driving Formula according to the Results shown.

$$R = \frac{W \cdot h \times \eta}{s + \frac{t}{2}} + (W + P)$$

η = efficiency of blow as calculated.

$$\eta = \frac{1}{\left(1 + \frac{P}{W}\right)} + \frac{\lambda^2}{1 + \frac{W}{P}} \text{ approx., taking } \lambda = 0{\cdot}25$$

Safe Working Load = L.

$$L = \frac{R + r_f}{4}$$

$$L = \frac{R}{10} \times 3 \text{ approx.}$$

P = weight of pile.
r_f = Frictional resistance on pile.
R = Ultimate resistance at shoe.
W = weight of hammer.
h = height of fall (inches).
s = permanent "set" per blow (inches).
t = temporary "set" per blow (inches).
t' to be measured by tape gauge.

Permanent "set" of pile into ground per blow of 2-ton hammer with fall h = 25 in., 50 in. and 75 in., shown above base.

Temporary "set" due to pressure p at shoe, shown by t below base.

Probable temporary "set" if it be calibrated is shown by the lower dotted line below base.

Thus $$\eta W h = R \cdot (s + \tfrac{1}{2} t)$$

and $$R = \frac{\eta W h}{s + \frac{1}{2} t},$$

from which R could be obtained.

Before proceeding to investigate more closely the actual values for t which such calibration may reveal, attention will first be called to the calculated results shown for the sets in Table VII. These have been figured out using the values given for the several efficiencies in Tables III to VI. The

permanent set s of the pile shoe in the ground (per blow)

$$s = \frac{\eta W h}{R}$$

and the temporary compression set t, at the head of the tube occasioned by the stress due to R

$$t = \frac{\eta_2 W h}{R} \times 2.$$

Fig. 5. CURVES OF EFFICIENCIES FOR VALUE OF p-2000 LBS. PER SQ. IN.

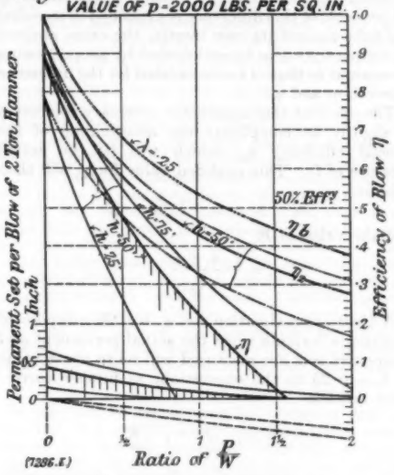
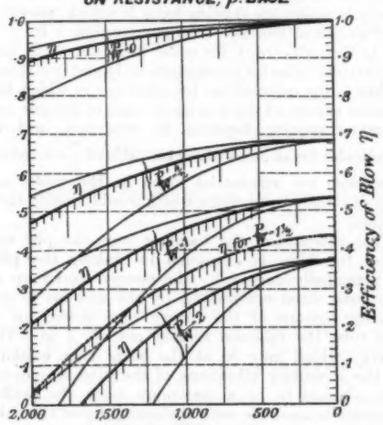


Fig. 6. CROSS-CURVES OF EFFICIENCIES ON RESISTANCE, p. BASE.



The factor 2 allows for the elastic stress-strain, diagram being triangular.

The amounts of s and t are given for the four values of p, postulated on abscissa values of $\frac{P}{W} = 0$, $\frac{1}{2}$, 1, $1\frac{1}{2}$ and 2, which covers all the ground required. The table has throughout dealt with the three heights of fall h for each case, of 25 in., 50 in. and 75 in., and it must be borne in mind that the value of h represents the effective fall, which is less than the measured amount for cases where resistances impede the falling hammer. Thus for a single-acting steam hammer, the loss of potential energy caused by the friction of the steamtight packing gland on the piston rod, and back pressure, will absorb about 5 per cent. to 6 per cent. of the fall, which would need 53 in. actual fall to be given to represent an effective fall of 50 in.

Also in the case where a monkey is caused to fall by the release of a friction brake at the winch by which this type of hammer is raised, the falling weight has also to start into motion the barrel of the winch, a heavy pulley, and the steel wire rope which reduces the accelerating force, and therefore the measured height by about 40 per cent., which would require 42 in. actual fall to represent the effective fall of 25 in.

The results given in Tables III to VII are plotted in the curves shown in Figs. 2 to 5, on a base of $\frac{P}{W}$. The curves for overall efficiency are shown in full lines; the centre one distinguishing the case for 50 in. fall of the triple heights assumed. The values of η_2 are also added to allow it to be seen what energy is used up in stressing the tube with the force R taken.

The upper curve, as in Figs. 2 to 5, indicates the value of η_6 using a value for $\lambda = 0{\cdot}25$. The amounts of the permanent set s for the four values of p in Table VII, are plotted above the base in Figs. 2 to 5, the 50-in. height of fall being again shown more prominently. The calculated values of temporary set t are indicated by the dotted straight line below the base of Figs. 2 to 5, because unlike the curves for s, its value is unaffected by the amount of h so long as some permanent set takes place and its value varies simply with the length of tube when transmitting a given force R.

Cross curves of efficiencies corresponding to fixed values of $\frac{P}{W}$ are given in Fig. 6 plotted for abscissa values of p up to 2,000 lb. per square inch.

As the information disclosed by these curves shows the sets obtained in relation to the efficiencies, and the latter are only of academic interest, the useful information comprising the sets s and t, the accompanying pressures p or forces R, and the respective ratios of $\frac{P}{W}$ or their equivalent length of pile tube, have been taken out and embodied in the trellis diagram, shown in Fig. 7, for convenience in practical use.

From this diagram the effect of a blow on a pile of given length against a certain resistance R, from a hammer of 2 tons having an effective fall of 50 in. can be seen by the length of the ordinates of the fences in terms of the permanent set produced. The average working conditions met with in practice are comprised within the confines of the two central enclosures, here the thickened main rail represents the permanent sets s for the general height of fall of

TRELLIS DIAGRAM SHOWING EFFECT OF HAMMER BLOW.

When driving 16-in. external diameter by ⅜-in. steel tubular preparatory piles: Permanent "set" of pile in ground shown by height of trellis rail above datum. Temporary elastic compression "set" shown by depth of webs below datum surface (1) due to stress p, (2) due to free impulsive force.

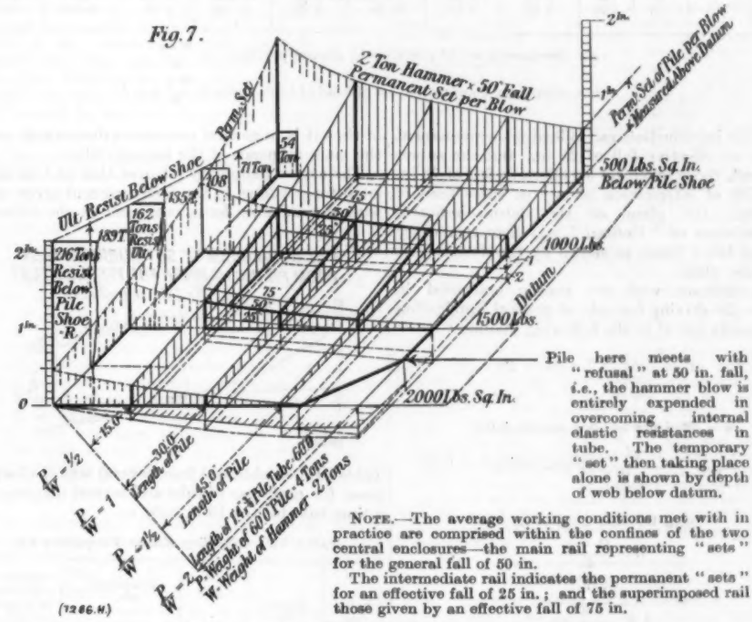
Diagram is drawn for various lengths of piles as indicated, and ratios of $\frac{P}{W}$ for selected resistances (ult.) to which pile may be required to be driven, and shows conditions where driving to "refusal" is encountered.

Particulars.

Hammer: single-acting, steam-raised cylinder of 2 tons weight; gravity drop, 4 ft. 6 in.; effective height of fall, 50 in.; pile shoe, 80 deg. full angle of point, 17½ in. extended diameter and 240 sq. in. projected area; ground pressures below shoe, as shown.

Efficiency of hammer blow to produce the set given, calculated after taking into account loss due to impact, using coefficient of restitution for hardwood driving cap of 0·25; also allowing for loss of energy in pile cap and hammer cylinder during blow.

Fig. 7.



Pile here meets with "refusal" at 50 in. fall, i.e., the hammer blow is entirely expended in overcoming internal elastic resistances in tube. The temporary "set" then taking place alone is shown by depth of web below datum.

NOTE.—The average working conditions met with in practice are comprised within the confines of the two central enclosures—the main rail representing "sets" for the general fall of 50 in.

The intermediate rail indicates the permanent "sets" for an effective fall of 25 in.; and the superimposed rail those given by an effective fall of 75 in.

NOTES FOR REINFORCED CONCRETE AND TIMBER PILES.

For application of the diagram to driving of:—

(1) Pre-cast reinforced concrete piles. The curves and particulars apply without modification where the pile is fitted with a helmet.

(2) Pre-cast reinforced concrete piles not so fitted: increase the values of η shown on curves of efficiency by 0·03, 0·05, 0·06 and 0·065 for values of $\frac{P}{W}$ of ½, 1, 1½ and 2 respectively, then increased the values of set, S, per blow in proportion, above those indicated by diagram.

(3) Timber piles: increase the set per blow by four times. The heights of fall shown on curves are also to be increased four times the values shown.

If hammers of other weights than the 2-ton postulated be used, modify the value of S by multiplying by the ratio of these weights.

In this class of piles driven through firm strata of gradually increasing resistance, as in average firm ground conditions, the greatest load L_1 to just avoid causing movement of pile, is approximately

$$L_1 = (R + rf) \div \frac{d^2 + \frac{d.l.}{10}}{d^2 + \frac{d.l.}{40}}$$

d and l being expressed in feet.

It will be found, even if $(R + rf)$ be allowed to approach 75 per cent. of the strength of the pile driven, the safe margin of resistance above working load to ensure that no settlement will take place is not so ample as that available in the case of cast-in-situ method of piling.

TABLE VII.—INDICATES THE PERMANENT SET AND ALSO THE TEMPORARY COMPRESSION SET OF THE STEEL PILE TUBE DRIVEN UNDER THE STATED CONDITIONS OF HEIGHT OF FALL OF A 2-TON HAMMER, AGAINST THE GIVEN RESISTANCE POSTULATED, AND IN ACCORDANCE WITH THE EFFICIENCIES OF HAMMER BLOW AS SET OUT IN TABLES III, IV, V AND VI.

Ratio of $\frac{P}{W}$	Weight of Pile and Length.	Height of Fall.	W h.	Sets for Condition p = 500 lb./sq. in. or R = 54 Tons.		Sets for Condition p = 1,000 lb./sq. in. or R = 108 Tons.		Sets for Condition p = 1,500 lb./sq. in. or R = 162 Tons.		Sets for Condition p = 2,000 lb./sq. in. or R = 216 Tons.	
				s.	t.	s.	t.	s.	t.	s.	t.
		in.	in./tons	in.	in.	in.	in.	in.	in.	in.	in.
0	0	25	50	0·91	0·0	0·44	0·0	0·27	0·0	0·18	0·0
		50	100	1·84	0·0	0·90	0·0	0·58	0·0	0·415	0·0
		75	150	2·75	0·0	1·36	0·0	0·89	0·0	0·64	0·0
½	1 ton 15 ft.	25	50	0·61	0·025	0·26	0·05	0·138	0·07	0·06	0·1
		50	100	1·26	0·025	0·59	0·05	0·35	0·07	0·22	0·1
		75	150	1·88	0·025	0·91	0·05	0·56	0·07	0·38	0·1
1	2 tons 30 ft.	25	50	0·455	0·05	0·172	0·10	0·053	0·15	nil	0·15
		50	100	0·95	0·05	0·42	0·10	0·215	0·15	0·10	0·2
		75	150	1·44	0·05	0·66	0·10	0·38	0·15	0·22	0·2
1½	3 tons 45 ft.	25	50	0·355	0·07	0·106	0·15	nil	0·20	nil	0·11
		50	100	0·76	0·07	0·31	0·15	0·122	0·22	0·008	0·3
		75	150	1·16	0·07	0·51	0·15	0·257	0·22	0·11	0·3
2	4 tons 60 ft.	25	50	0·285	0·10	0·052	0·20	nil	0·16	nil	0·08
		50	100	0·63	0·10	0·225	0·20	0·046	0·30	nil	0·25
		75	150	0·97	0·10	0·40	0·20	0·162	0·30	0·017	0·4

s = permanent set of pile shoe in ground per blow = $\frac{W\,h\eta}{R}$

t = temporary compression set of head of tube stressed $\frac{W\,h}{R}\,\eta_5 \times 2$

50 in. The intermediate rail indicates the permanent sets for an effective fall of 25 in., and the superposed rail, those given by an effective fall of 75 in. The point of intersection of any of these lines of rails with the plane of the datum indicates the conditions of "Refusal," and here temporary set alone takes place, as shown by the dotted lines below the plane.

In accordance with the results embodied in Fig. 7 a pile-driving formula of general application can be made use of in the following manner:

$$R = \frac{W \,.\, h \times \eta}{s + \frac{t}{2}} + (W + P)$$

η = efficiency of blow as calculated

$$\eta = \frac{1}{\left(1 + \frac{P}{W}\right)} + \frac{\lambda^2}{1 + \frac{W}{P}} \text{ approx., taking } \lambda = 0{\cdot}25$$

Safe Working Load = L.

$$L = \frac{R + r_f}{4}$$

$$L = \frac{R}{4 \times \frac{d^2}{d^2 + \frac{d\,l}{4\,0}}}$$

P = weight of pile.
r_f = frictional resistance on pile.
R = ultimate resistance at shoe.
W = weight of hammer.
h = height of fall (inches).
s = permanent "set" per blow (inches).
t = temporary "set" per blow (inches).
t'' = to be measured by tape gauge.
d = dia. of pile or side in feet.
l = length of pile in feet.

It will be observed on referring to Fig. 7, that in addition to the temporary elastic compression set caused by the pressure p, a further amount is indicated by the bottom layer of the webs shown below the datum line. This corrective addition to the temporary set beyond that due to p has been brought about as will be briefly described.

With a view to examining to what extent the impulsive shocks set free to stress the pile at the instant of impact could further add to the elastic strain as calculated for a steady pressure from the shoe compressing the pile in its length, occasion was taken to calibrate the temporary strains during the driving of several test piles of 25 ft. and 15 ft. length at the Simplex Concrete Piling Company's works at Edmonton during October of last year.

The results obtained confirmed the opinion of the author that some part of the energy assumed, so far in the calculations tabulated for a value of $\lambda = 0{\cdot}25$, to be wholly lost in heat energy, includes, in point of fact, a portion which was free to induce the noticeable longitudinal vibration in the tube which takes place throughout the short space of time it is in general movement downwards under the main influence of the hammer blow.

The excess temporary set over that of t, as calculated for p values in the foregoing and given along with the amounts for s, is set out in the following

Fig. 8. DIAGRAM OF SET DURING A BLOW FROM PILING HAMMER FOR 15FT. PILE TUBE.
W-2 Tons h-25 ins.

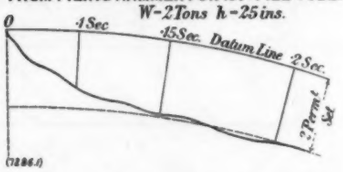


Table VIII as obtained from several sets of observations for each size of tube and several diagrams on a time base for the 15-ft. tube:—

TABLE VIII—*Showing Excess Temporary Set.*

Ratio of $\frac{P}{W}$	Height of Fall of 2-Ton W	s.	Temporary Set.		Approx. t, Allowing 50 per cent. of Diff. in η_0 for $\lambda = 0{\cdot}6$ and $\lambda = 0{\cdot}25$.
		Actual	t Calculated.	Actual.	
	in.	in.	in.		
0·5	25	2	0·01	0·1	0·07
0·5	38	1¼	0·02	0·1	0·08
0·8	38	0·13	0·14	0·25	0·10

The above sets were measured by a tape gauge rigged up for the purpose. In this a narrow linen tape measure is affixed to a stud on the pile and carried upwards through a clamp which grips it to a fixed stand, such as a step ladder, but allows it to pull through by the movement of the pile and thus indicate the maximum travel and, when the slack is returned by the observer, the permanent travel, the difference between the two being the temporary set.

The diagrams obtained were similarly provided and set up in place. Here the marker is carried on the upper end of a light wood rod and set against the plain surface screwed to the stand used for the observer. The lower end of the rod, some 3 ft. long, is secured to a fixture on the side of pile. To the upper end of the rod a cord is attached leading over a pulley to a weight of about a stone. The end of the rod is rigged up to engage with a small catch which retains it from being pulled across the marking surface until the pile has commenced to move under the blow. Thereupon the marker is flashed across and the diagram marked on the surface provided. Fig. 8 shows a diagram as obtained in the first example.

Accordingly, on Fig. 7, the additional temporary set has been added to account for the extra vibrating oscillation which may take its origin from the free impulsive force supposed.

An additional curve of efficiency has been drawn on Fig. 4 showing the values of η_c for a value of $\lambda = 0{\cdot}6$ for bodies of solid steel under impact, the other curve for η_b being for a value of $\lambda = 0{\cdot}25$.

Taking at each ordinate of $\frac{P}{W}$ the difference between these curves, we obtain when assuming 50 per cent. of this difference is expended in stressing the tube against its own inertia, the extra amount of temporary set to be anticipated by proportioning its amount to that of t as calculated for the difference between η_2 and η.

The effect of this apparently necessary correction is slightly to complicate the determining of the overall efficiency η_0, which will be the actual measure of t_1. This modified value for η_0 will then become

$$\eta_b - \eta_1 - \eta_3 + \tfrac{1}{2}(\eta_c - \eta_b)$$

and the value of R

$$= \frac{W \,.\, h \times \eta_0}{s + \frac{t_1}{2}}$$

A close approximation for η_0 for the purpose of applying a formula when the actual permanent and temporary sets are measured will be to use a value of $\lambda = 0{\cdot}25$ in the expression, as further corrections balance

$$\eta_0 = \frac{1}{1 + \frac{P}{W}} + \frac{\lambda^2}{1 + \frac{W}{P}}$$

In the calculations for efficiency dealing with bodies of partial elasticity as in all instances met with in piling, the hammer maintains contact with the pile whilst the driving force is acting, provided the weight of hammer W is greater than λ P.

As the value of λ for wood and iron, 0·25, and the virtual value for a composite body and iron is well below ½, the calculations for efficiency in which the kinetic energy of the combined mass of the pile and hammer moving together is admitted, will be applicable for all cases where the ratio of $\frac{W}{P}$ exceeds ½. Therefore the efficiencies given in the tables are out of range of principles which would modify their values.

The rebound of the hammer from the pile cap after the blow is expended in sinking the pile, is principally caused by the energy stored up in the tube when compressed by the amount t, and taking account of the energy thus stored up in the tube the rebound seldom reaches 1 in. The energy which may be at the same time existing in the secondary vibrations of the tube may cause the rebound to be a maximum when the period happens to coincide with the spring up of the tube from the spent blow. Were the hammer to be of less weight than W = λ P, a species of cavitation occurs in which the useful energy owing to the separation of the hammer from the pile, leaves available only an amount

$$= \tfrac{1}{2}\,\frac{P}{g}\,v_p^2$$

against the full value

$$\tfrac{1}{2}\,\frac{W}{g}\,v_w^2 + \tfrac{1}{2}\,\frac{P}{g}\,v_p^2.$$

Also it follows the blow administered from a hammer of so low a ratio of $\frac{W}{P}$ as to bring it within the "cavitation" limit will give out an energy which is relatively small, and which requires a compensating advantage of speed, as is met with in double acting hammers or extractors, to justify the low ratio.*

(To be continued.)

STORAGE OF AIRCRAFT TIMBER.—A leaflet giving notes on the conditions for the storage of seasoned aircraft timber previous to conversion has been issued by the British Engineering Standards Association, 28, Victoria-street, Westminster, S.W. 1.

* We regret to find that a small error crept into the first part of this article, which appeared in our last issue. On page 674, column 1, line 8 from the top, the value for E_1 there expressed in pounds per square inch should read 3 × 10⁶ and not 30 × 10⁶ as printed.

INDUSTRIAL NOTES.

IT cannot be said that Mr. Clynes was very helpful in his remarks on the unemployment question, in his presidential address to the National Union of General Workers. He contends that those who reject what Labour proposes should suggest some effective alternative. This, however, is not a fair statement of the position. Labour proposals are rejected because every competent student of economics knows that whenever similar plans have been tried in the past they have proved ruinous, the worst sufferers being the "common people." Both directly and indirectly Labour has for many years past promoted unemployment to the best or the worst of its capacity. Before the war it opposed every practical scheme for cheapening the supply of power. The legislation which brought electrical progress in this country to a standstill has never been criticised by Labour, although the result was, that thousands of workmen, who would have found well-paid employment in our heavy electrical industries, have had to find work elsewhere, whilst when development by the municipalities became practicable, equipment had to be purchased on an enormous scale from abroad. Mr. Clynes asks for an effective alternative to the futile and absurd proposals of his party, and we have pleasure in acceding to his request. Let the Labour Party abandon its craze for municipalisation and nationalisation, and its restrictions on output and on the doing of unskilled work by unskilled labour and we will guarantee that the unemployment problem will soon be reduced to manageable proportions. Listening to a labour leader deploring unemployment reminds one of the Kaiser's heart bleeding for Louvain.

In one part of his address, Mr. Clynes appears to be guilty of a serious misrepresentation. He asserts that a "Bill is being pressed in Parliament with the object of preventing trade unions gathering political subscriptions from their members even after a ballot vote has declared a willingness to pay them." As he perfectly well knows, the Bill does not aim at preventing a subscription being collected from any member who is willing to pay it. The view of the promoters of the Bill is that political creeds ought legally to stand on the same footing as religious creeds, and the non-conformists years ago refused to accept as a solution of the Church rates question, the present procedure of the trades unions by which a man is assumed to be willing to support the official creed so long as he does not formally protest.

Mr. Clynes also protests against the frequency with which the advice of the union leaders is rejected on the instance of local officials. He observes very justly that "A serious weakness in trade union organisation arises from conflict in the degrees of leadership within the unions. There are men whose only pathway to influence or notoriety is to attack those who happen to be responsible officials. They act on the wicked assumption that the chief leaders have some interest apart from that of their members. There is no satisfaction to the responsible official greater than that of securing for his men the best possible bargain, and his preference for a victory is as real as that of any other man. But there are times when he must tell his members what cannot be won, and warn them of the losses certain to be incurred by following a course which less informed men may advise. Men who make difficulties for officials merely to make room for themselves have done serious mischief in a number of recent cases, and experienced leaders who are not given proper authority and full confidence are weakened in their work, and can never be on equal terms with the spokesman of employers who can always depend upon the support and approval of the capitalist interests which they are chosen to advance." The last sentence ought to be confronted with Mr. Clynes' protest in the April issue of the *World's Work* that employers had in certain cases refused to accept arbitration. Up to the present, however, whenever employers have agreed to arbitrate, they have honourably and honestly accepted the award, but there have been repeated instances in which the men have refused to accept an unfavourable award. The same article also affords a good deal of justification for the resistance of local officials, when the union leaders advise the men to yield on some point in dispute. Mr. Clynes declares in the article in question, that employers have seized the opportunity of the prevalence of unemployment to force down wages. If this were true and the employers' action were, as seems to be suggested, due to pure malignancy, it is not surprising that local leaders refuse to accept reductions, and in this action, were Mr. Clynes' major premise correct, they would have the support of all fairminded citizens. Obviously, however, the prevalence of unemployment constitutes in itself proof that the employers' action is not unwarranted. Orders cannot be obtained unless costs are reduced, and the unions strongly resent this being effected either by dilution or by improvements in plant which may involve a reduction of piece rates, even though such reductions may be accompanied by no diminution in total weekly takings. It is, in fact, probable that the machinery now used in our boot factories could never have been developed here owing to trade union opposition. Each new machine would have involved a dispute, which would more than offset the possible savings due to it in its early stages of development. The machines had accordingly to be developed elsewhere to the great profit of American workmen, and when perfected, had to be accepted *en bloc* by our own men, as the alternative was the extinction of the trade.

In accordance with the National Wages Agreements entered into by the National Federated Electrical Association and Electrical Trades Union under dates August 7, 1920, and September 22, 1921, it has been decided that the variation in cost of living justifies a 22 per cent. reduction in wages in lieu of the previous reduction of 16 per cent., and that the net hourly rates of pay applicable to the respective grades for the ensuing four months will be as follows: Grade A, 1*s.* 11½*d.* (this rate includes a travelling allowance; no further allowances to be paid except as provided by Rule 9 of the London Rules, dated February, 1920); Grade B, 1*s.* 9*d.*; Grade C, 1*s.* 7½*d.*; Grade D, 1*s.* 6*d.* The above rates will come into effect on the second pay day in June, 1922, for the period covered by that pay day, and will remain current up to and including the period covered by the first pay day in October, 1922.

The engineering deadlock appears to be nearing its end, and there are confident predictions that peace will be restored within the next fortnight. The forty-seven unions have accepted the terms offered by the employers, the vote being 99,313 in favour of a settlement and 46,881 against. The latter figure includes the boilermakers' vote, which was overwhelmingly against an agreement. The obstinate refusal of the members of this Society to recognise that customers cannot be found for their class of work at present prices is most lamentable. In the end they must yield to the inevitable, as sufficient work to keep our ship and boiler yards in reasonable activity cannot be obtained without a substantial reduction in labour costs. The profitless dissipation of the trade union funds in a hopeless resistance will benefit no one. This we note has been recognised at Birkenhead, where, in spite of the vote, the boilermakers have decided to return to work.

It is reported that the skilled men in the Manchester area were also strongly against a settlement, but were outvoted by the general workers attached to their union. The A.E.U. conference at York has, however, decided on a second ballot, and the responsible leaders are strongly urging an acceptance of the employers' terms. Some such action was inevitable, as funds are no longer available for maintaining the grants to the locked-out men. Once the ill-advised and ill-informed resistance of the men to the efficient operation of our engineering works is abandoned, more prosperous times may be anticipated. The average net weekly takings of the members of the A.E.U. will thus be increased owing to the consequent diminution of unemployment. Some of the delegates at the York conference advocated the calling out of all members from all sources of employment, with the exception of hospitals. This foolish policy, which, when adopted on other occasions, has invariably failed, was defeated by an overwhelming majority. As for the prophecies of evil if the employers' terms are accepted, Mr. Brownlie states that the employers' "proposals are mild in comparison to the terms of settlement imposed upon the engineering unions at the end of the great lock-out in 1897–8, when many of us thought that the 'terms of settlement' were the end of all things so far as engineering trade unionism was concerned, as many of us thought at that period the terms of settlement crippled beyond recovery the activities of our organisation, but subsequent events falsified our prognostication, as during the period in which we recognised procedure for avoiding disputes the members of the engineering unions gained concessions of greater value in comparison to any concessions obtained during the preceding 25 years, without having recourse to drastic action." This testimony as to the relative merits of truculence and friendly negotiation seems worthy of record. It must, however, be borne in mind that many unreasonable and unfair concessions were exacted during the war, when the union, metaphorically speaking, held a pistol to the throat of the nation, and refused necessary supplies to the men at the front, save on their own terms.

"THE ELASTIC LIMIT."

TO THE EDITOR OF ENGINEERING.

SIR,—In the excellent leading article on failure by fatigue, in your issue of April 28, a statement is made which shows how lax is our scientific nomenclature. The statement in question reads as follows: "One interesting result was that the ultimate strength of the material was a somewhat more reliable index of its endurance than was the elastic limit." The elastic limit is defined as being the maximum stress which can be impressed on a material without causing any other than purely elastic deformation. It follows from the definition that if the elastic limit is not exceeded the material recovers fully when the stress is removed, and the material will withstand such a stress for an indefinitely long period, whether it be constant or variable, unidirectional or alternating. It would, therefore, be logical and preferable to invert your statement and to say that if an alternating stress is applied to a specimen and it fail, the stress exceeds the elastic limit, and if it does not fail, that the stress is below the elastic limit. In other words, the elastic limit of a material cannot be determined by a tensile test, but it is possible to find the value approximately by means of a series of Wöhler tests. I suppose it is all a matter of confusion between "yield-point" and "elastic limit."

Yours truly,
S. F. BARCLAY, D.Sc., M.Inst.C.E.

Manchester, May 3, 1922.

[No doubt, as our correspondent implies, the elastic limit of a material is far from satisfactorily defined. There is, however, much reason to believe that this unfortunate state of affairs is in the main due to the irritating perversity of our materials of construction, which resolutely refuse to fit themselves accurately to the formulas devised to represent their properties. This behaviour, indeed, led Professor H. Bouasse, many years since, to declare that there was no such thing as an elastic limit, as when sufficiently delicate methods of observation were used no material was found to obey Hooke's law over a finite range of stress. Moreover, a time factor enters in the relationship between stress and strain. Chronometer makers tell us that a new chronometer takes a year to settle down to a steady rate, and should the chronometer be subsequently dismantled for cleaning it will not, when set going, again revert to this steady rate till after the lapse of some weeks. The stress on the spring, which is, of course, of a very high quality steel, is of the order of ± 9 tons per square inch. Our correspondent's proposal would seem to involve the abandonment of any connection between the elastic limit and Hooke's law, and he would make it identical with the limit of endurance. No doubt the proposal can be defended, but we fear it would lead to confusion in practice. A structure which is given a permanent set is often strengthened by the process and its endurance increased; as, for example, the cylinders used by Professor Bridgman in his experiments with intense hydraulic pressures. It would, to say the least, be confusing to hold that the material of such cylinders had not been strained beyond its elastic limit. On the whole it seems preferable to distinguish between the limit of endurance and the elastic limit, even if we have to define the latter, somewhat vaguely and indefinitely, as the limit at which stress ceases to be sensibly proportional to strain.—ED. E.]

"THE FIRST STEP."

TO THE EDITOR OF ENGINEERING.

SIR,—I have just read your refreshing article on "The First Step." That same spirit of willingness, responsiveness and straightforwardness to which you refer, I can testify, has been helpful to me in my varied experience with my fellow workmen and employers, and is helpful in every phase of life. At the present moment when we are unemployed, we have time "to reflect and contemplate on the great world around us." In my experience of machine shops I have seen men placed in positions of authority through "red tape" and influence who were not qualified to hold such positions as leaders or directors of the workshop, but had secured such positions by having (to use a concise, concrete definition or vulgarism), "a brass face." It is largely by the imprudent choice of such men by employers that there is so much industrial unrest and "grousing" in the engineering industry.

Yours, &c.,
"AN UNEMPLOYED MACHINIST."

June 3, 1922.

STANDARDISATION OF SHIPS' FITTINGS.—Three specifications recently issued by the British Engineering Standards Association, 28, Victoria-street, Westminster, S.W. 1, relate, respectively, to table glass and crockery for use on ships, oil lamps, and locks for ships' joinery work. These specifications have been drawn up by panels on the Clyde and on the North East Coast, and that first mentioned deals with the shape and dimensions of cups and saucers, plates, water bottles, tumblers, &c., while that relating to lamps covers the duration of burning and the material and thickness of the container. With regard to locks, since most of the better class of these fittings are patented, the mechanism has not been specified in detail, but the type of lock, overall length, diameter of spindle and the material are dealt with. In all cases approximate metric equivalents are given for the dimensions, to facilitate the use of the specifications in foreign countries. The specifications are published by Messrs. Crosby, Lockwood and Son, 7, Stationers' Hall-court, E.C. 4, at the price of 1*s.* each net or 1*s.* 2*d.* post free, and they are obtainable from any bookseller, or direct to the offices of the Association at the address given above.

THE COLLINS MICRO-INDICATOR FOR HIGH-SPEED ENGINES.

CONSTRUCTED BY THE CAMBRIDGE AND PAUL INSTRUMENT COMPANY, LIMITED, LONDON.

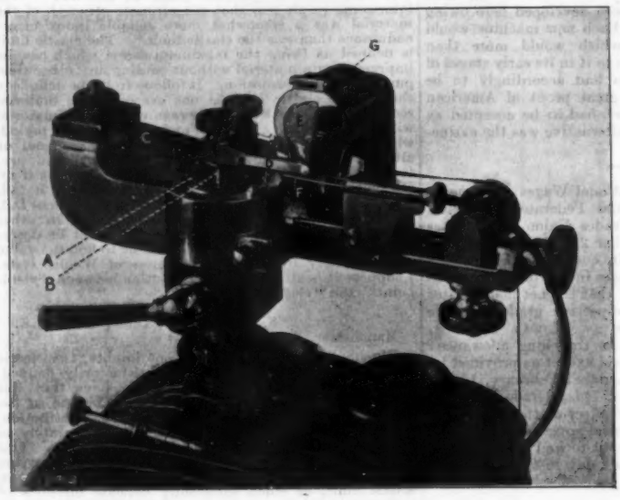
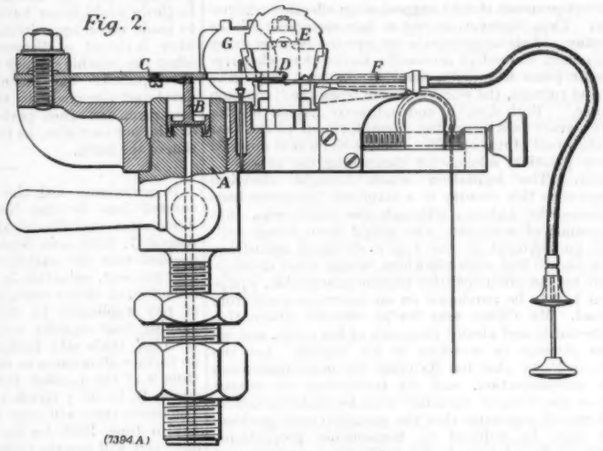


FIG. 1.

Fig. 2.



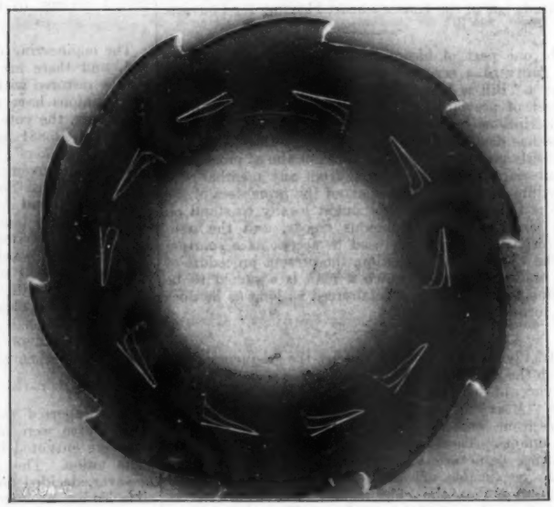


FIG. 3.

THE micro-indicator constructed by the Cambridge and Paul Instrument Company, which we illustrate in Figs. 1 to 3, annexed, was one of the striking novelties of the Royal Society Soirée of this year, and was mentioned in our notice of these exhibits, on page 630 *ante*. We need not dwell upon the utility of an instrument which, within half a minute, almost automatically, will produce 10 successive permanent records of the performance of a high-speed engine on a card which is ready either for immediate inspection and measurement in a very simple microscope, used after the manner of a pocket telescope, or for photographic enlargement. Indicator diagrams taken at rapid intervals not uncommonly draw the attention of the designer or manufacturer of an engine to unsuspected or obscure defects, in a manner which enables him to determine the cause of the poor performance, and the convenience of the micro-indicator will be particularly appreciated on motor cars and on flying machines when track tests or trial flights are being conducted, and where there is neither space nor time for elaborate instruments and methods of testing. The records are mechanical, not optical or photographic, and the operator need not leave his seat to take them. The micro-indicator has been designed by Mr. W. G. Collins, director of the Cambridge and Paul Instrument Co.

The indicator consists of a cylinder A and a piston B (Figs. 1 and 2), both made of a hard non-corrodible metal. The rising piston forces upward the flat spring C to which the style D is attached; the style scratches a record on a slightly curved disc or card of celluloid E which is provided with 10 notches; the diameter of the disc is about 1 in. This disc is carried by a frame attached to the front sector of a small vertical post; a back sector on the same post is rocked to and fro' by a connection to the piston of engine; the post also supports the helical spring which takes up any back lash.

The style D scratches a small indicator diagram on the surface of the card. This action takes place when the Bowden wire is operated, causing the pawl F to press against one of the 10 notches of the disc; the disc turns about its horizontal axis by one-tenth of its circumference, each time the Bowden wire is moved, so that 10 consecutive diagrams are drawn near the circumference of the card. Contact between the style and the disc is, however, only possible when the automatic electric switch of the indicator energises the iron-clad electromagnet G which will be seen at the back of the card, and which draws the parts into contact by means of a small chain which extends from the armature to a pin close to the style.

This switch, another ingenious piece of apparatus, is not shown in our illustrations; only the two switch terminals to which the switch wires are attached being visible on the left-hand side. The switch is actuated by a belt from the engine, and its object is to permit of taking a single cycle only, and thus to avoid confusion when the diagram is rapidly changing its forms due to variation of load, ignition, carburation, &c. The switch circuit is ordinarily open, *i.e.*, the style does not touch the disc, until the key of the switch is pressed. Without this device the consecutive records might overlap and be spoiled, because the style contact might be maintained for more than a complete cycle of the engine under test. The whole instrument which is mounted on the top of the engine cylinder, weighs only about a pound. The moving parts are light and they move through small distances; there is little inertia, an entire absence of linkages and uncompensated joints, and there is, therefore, small liability to wear. With a piston area of $\frac{1}{4}$ sq. in. the natural period of the recording system is about 1/1100 of a second.

The actual indicator diagrams obtained measure about 3 mm. in length by 2·5 mm. in height. The raised edges of the scratch render the records very distinct in spite of their small size. Examined in the microscope we mentioned, with a scale or a graticule in the field of view, the diagrams are quite convenient for area measurements. The microscope is merely a tube prolonged to form a simple frame; the disc is placed in a slot in the frame, and the tube is then raised so that the light from a window or lamp falls through the celluloid disc from behind; there is no special substage nor illuminator. Dimensions may be read correctly within 0·01 mm. Some photographic enlargements of the diagrams are reproduced in our Fig. 3; enlargements of 20 diameters will usually be sufficient.

LIGHT-METAL PISTONS FOR AUTOMOBILE ENGINES.

UNDER the auspices of the German Transport Ministry and the Verein Deutscher Motorfahrzeug-Industrieller, competitive trials of light-metal pistons for automobile motors were last summer held in Berlin. These very extensive and varied tests were conducted in the experimental department for automobiles of the Technical High School, Berlin-Charlottenburg, by Professor Gabriel Becker, Dr. Ing., chief of that department, who personally bore a large share of the expense. In the tests and analyses, which are still being continued, Dr. Becker had assistance from outside, in addition to the services of the staff of his department comprising six engineers, and further of a considerable number of the students of the High School, for whom the systematic investigations were of great value. Nine firms, metallurgical and engineering works, took part in the competition, upon which Dr. Becker has presented a very instructive monograph,* embodying suggestions for further advance. Dr. Becker's advocacy of light-metal pistons dates back more than ten years, when he was working with the firm of Messrs. Basse and Selve.

The 32 sets, each of 4 pistons of 16 different light metals submitted, may roughly be classed as aluminium alloys, comprising two silumin alloys of aluminium with 11·4 per cent. and 15 per cent. of silicon respectively, and magnesium alloys, including an almost pure magnesium. Two sets of cast-iron pistons and one piston of pure electrolytic copper were also tested. As to weight the Al-alloys were from 15 per cent. to 25 per cent., and the Mg-alloys from 25 per cent. to 35 per cent. lighter than the cast-iron pistons. We give opposite a tabular summary of the analyses. The pistons were cast in dies with iron core or sand core, or pressed, as indicated in the last column. The Brinell hardness numbers are also stated in the Table.

All the pistons were tested in two motors of very different types, a 45-h.p. Daimler lorry motor, from the Daimler Company at Marienfelde, Berlin, and a new type of Protos touring car engine of 10 h.p. to 30 h.p. from the Protos Automobile Company, of Siemenstadt, Berlin. Both firms placed their motors at the disposal of the committee. The Daimler motor is a four-cylinder engine, two cylinders in one block, with cylinder diameter of 120 mm. and a stroke of 160 mm. (4·7 in. and 6·3 in.); the stroke volume is 1·809 litre (0·4 gallon), the compression volume with cast-iron piston 0·584 litre, and the compression ratio

* Vervollkommnung der Kraftfahrzeug motoren durch Leichtmetall-Kolben. By Professor Gabriel Becker. München and Berlin: R. Oldenbourg. (95 pages, small quarto; price 75 marks.)

4·1. There is no jacket space between the two cylinders of a pair; all the valves are arranged in the cylinder head; the air drawn in is preheated by the exhaust. The Pallas carburettor is not heated, and there is only one spark gap for the Bosch magneto; the speed ranges from 300 r.p.m. up to 1,200 r.p.m.

The Protos motor is constructed for speeds of from 600 r.p.m. to 2,000 r.p.m., and has four cylinders in one block; the cylinder diameter is 80 mm., piston stroke 130 mm. (3·15 in. and 5·1 in.), stroke volume 0·653 litre, compression volume 0·176 litre, ratio of compression with cast-iron piston 4·7. The valves are mounted on one side of the block, and the combustion chamber is nine times as wide as high; there is again one spark gap for the Siemens-Schuckert magneto.

The normal valve lifts for both engines are small, namely, 0·2 mm. (Daimler) and 0·3 mm. (Protos); with the heating of the engine the former increases by 0·2 mm. the latter decreases by 0·1 mm. The lubricant circulates in both motors under pressure, the oil bath being in the lower portion of the crank casing; special devices for lubricating the piston shafts and pins are not provided.

As regards the shape of the combustion chamber, the arrangement of the suction pipe, and the fuel economy and ease of regulation, the Protos motor was decidedly inferior, and the test conditions differed therefore considerably in the two motors. The motor tests were conducted in the usual way. The physical, thermal and chemical properties of the various piston materials were first determined in special apparatus, and the piston, ready for use, was then mounted in a water-jacketed steel cylinder in which the piston head could be heated to 600 deg. C. while thermocouple readings were taken at 10 points, distributed over the pistons (see Fig. 1), most of the holes for the thermocouples ending within 2 mm. of the outer piston surface.

The fuel used was mostly a benzol of density 0·875, the lubricant Gargoyle mobile B B. The wear of some parts showed that a thin oil of low viscosity should not be used in air-cooled motors at high temperatures, nor a thick oil of high viscosity in water-cooled motors. In this respect the Protos motor proved superior. The above-stated compression ratios for cast-iron pistons could safely be exceeded with all the alloy pistons, even with the cooling water at boiling-point and on the hottest summer days; most of the light-metal pistons bore compression ratios of even 5·7 without pre-ignition or pinking, and this ratio is recommended as most favourable for such pistons. When the benzol contained some petroleum, this high compression was only advisable with well-cooled cylinder walls; the fuel nozzles should also be made smaller for high compression.

The higher compression is possible because the light-metal piston does not become so hot as the cast-iron piston, and this factor favourably influenced the thermodynamical conditions and the working generally at all speeds and loads. The motor efficiencies were raised while the fuel consumption was lowered. The exhaust temperature and heat losses in the cooling water were diminished. When the load was decreased as it would on easy level runs at moderate speed, the saving in fuel might rise 35 per cent. The lorry gave on an average 8½ h.p. more, when fitted with a light-metal piston than with cast-iron, that is 20 per cent. more power while consuming 20 per cent. less fuel. The power losses due to friction were about the same in both cases, but the light-metal pistons required only half the amount of lubricant. As regards the vertical vibrations of the motors there was little difference.

The thermal features of the pistons call for particular notice. We mentioned above that 10 thermocouples were used to study these relations; the positions of these thermocouples are indicated by the numbers (1), (2) . . . (10), in Fig. 1; Fig. 2 represents some of the results. The heat flow would generally seem to be in the sequence of the numbers, that is to say, from the centre of the piston head to its edge and then down the shaft. The copper piston of the same shape as the others was also tested for the sake of comparison. The gas temperature in the cylinder was 300 deg. C., and the water temperature in the water-jacket is said to have ranged from 20 deg. to 24 deg. It will be seen that the head of the copper cylinder acquired a temperature of 30 deg., and that temperature was practically the same in all the other parts of the piston.

Fig. 2.

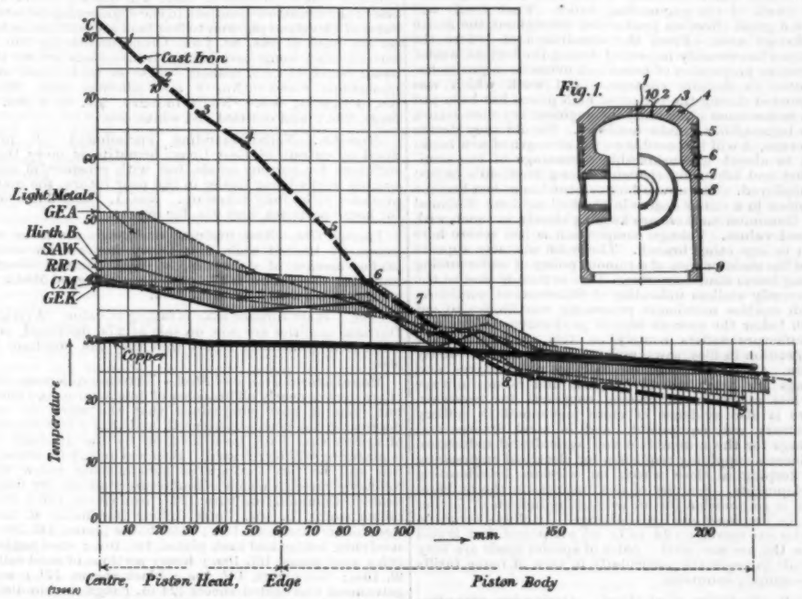


Fig. 1.

Fig. 3.

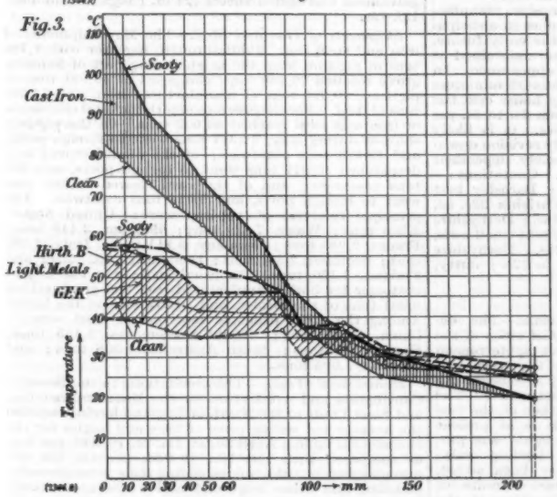


FIG. 4. FIG. 5.

ANALYSES OF EXPERIMENTAL PISTONS.

Mark.	Alloy.									Hardness.	Preparation.
	Al.	Cu.	Fe.	Si.	Zn.	Pb.	Sn.	Mg.	Ca.		
Hirth F ..	80·1	15·7	2·4	0·7	0·9	trace	—	—	—	120	Die and iron core.
Hirth B ..	82·8	14·6	1·2	0·7	0·6	0·1	—	—	—	111	,, ,,
Hirth E ..	83·6	14·0	1·6	0·4	0·6	—	—	—	—	101	,, ,,
M N ..	87·5	10·4	—	—	—	—	3·3	—	—	94	,, ,,
S A W ..	87·1	5·9	2·7	3·4	—	—	—	0·9	—	110	,, ,,
R R_1 ..	84·5	12·3	1·1	1·8	0·1	—	—	—	—	84	Die and sand core.
H B ..	88·9	11·7	—	—	—	—	—	—	—	106	,, ,,
K B ..	86·3	11·2	1·2	—	—	—	1·6	—	—	105	,, ,,
B M W ..	88·5	10·8	1·5	0·1	0·1	—	—	—	—	93	,, ,,
M W O ..	88·9	7·6	3·4	—	—	—	—	—	—	87	,, ,,
R R_2 ..	88·5	—	—	11·4	—	—	—	—	—	68	,, ,,
R R_3 ..	85·0	—	—	15·0	—	—	—	—	—	67	,, ,,
G E A ..	12·0	—	—	—	—	—	—	88·0	—	93	Pressed.
C M ..	0·4	—	—	—	—	—	—	99·5	0·1	48	,,
G E K ..	—	13·5	—	0·3	—	—	—	86·2	—	64	,,
K 15 ..	—	15·4	—	0·2	—	—	—	84·3	—	67	,,

There was in particular no temperature fall near the edge of the piston head, between couples (4) and (5), and that edge was not marked on the other curves either; nor did the piston rings, near (7), carry off much heat. In the cast-iron piston we find a very marked though fairly steady temperature gradient. The centre of the piston head was at 83 deg.; near the edge the temperature was still 57 deg., that is, far hotter than the copper piston, while near the bottom of the piston the temperature went down to 20 deg.; in the skirt of the piston the temperature gradient was 38 deg., whilst it was only 5 deg. in the case of copper.

The light-metal pistons ranged between the iron and copper pistons. The maximum temperatures in the piston head lay between 40 deg. and 50 deg.; at the lower end of the shaft they all had temperatures of about 23 deg. The G E K alloy (Mg-Cu) came nearest the almost ideal copper, while the G E A (Mg-Al) proved the poorest alloy in this respect; it is noteworthy that the CM alloy (not marked in the diagram, but practically Mg, with 0·4 per cent. of Al) proved only slightly inferior to the G E K.

Fig. 3 shows the difference which the deposition on the piston of soot made in these tests. The sooted piston heads became in all cases much hotter than the clean metals, and particularly so in the case of cast-iron. The points which affect this feature are the heat conductivity and the quantity of heat which the piston takes up from the hot gases; that quantity was found to be 30 per cent. lower for the light metals than for cast-iron. The sooty surface enabled the metals to take up 2·6 times more heat than the clean surface.

As regards ease of running and wear all the pistons were submitted to a continuous run of 4 hours, followed by longer runs; further reports are to be published regarding the latter. Whether much reliance can be placed on examination following a 4-hour run, may be questioned; but it was considered—and confirmed by the further trials—that these tests brought out the characteristic features. Unquestionably hardness of the piston material favours steady running and keeps the wear down. The hardness was determined by the Brinell method, and the materials gave hardness numbers in kilogrammes per square centimetre, ranging from 194 for the cast-iron down to 120 for the hardest aluminium alloy and 67 for the softest, and from 67 to 48 in the case of the magnesium alloys. But hardness is not alone to be considered. A magnesium alloy of hardness of 60 proved equivalent to an aluminium alloy of hardness of 100, because the aluminium tends to "smear" more than the magnesium does. As soon as magnesium is alloyed with aluminium, the alloy takes from this point of view the character of an aluminium alloy. Thus it was found that the pistons of cast-iron, of the hardest Al-alloy and of the Mg-alloy G E K suffered practically the same wear.

The two photographs, reproduced in Figs. 4 and 5, which Dr. Becker has sent us, were taken in March (*i.e.*, subsequent to the publication of the report) after a full-load run of 100 hours of the G E K piston in the Daimler motor. The motor gave 47 h.p. to 50 h.p. at a benzol consumption of from 228 grammes to 236 grammes per hour, the oil consumption being 90 grammes per hour; this oil consumption went down to 55 grammes and to 30 grammes at two-thirds and one-third loads. The diameters of the four cylinders had increased by 0·003 mm., 0·008 mm., 0·006 mm. and 0·015 mm; no reduction of the piston dimensions was then measurable. The photographs show the piston in the uncleaned condition; the piston, piston rings and other parts were considered to be in good condition.

The report further discusses other features, notably the construction of the pistons, their shapes, the mounting and piston rings and bolts, and the clearance, &c., points which largely depend upon the thermal expansion, but which cannot profitably be explained without full diagrams. The expansion coefficients of the various alloys were nearly twice as large as that of cast-iron (from 244 to 288 against 136 in the case of cast-iron, all in 10^{-7} units), but the clearance, it is said, need only be increased by about 50 per cent. Cylindrical pistons without ribs and with narrow rings (3 mm. to 4 mm. in height) are recommended. In the final order of merit the G E K stands first, followed by the aluminium pistons Hirth B and Hirth E and the G E A piston (Mg-Cu). The addition of about 12 per cent. of copper to either aluminium or magnesium seemed to be advantageous.

HEAT TREATMENT OF ALUMINIUM ALLOYS.—Notes on the heat treatment of wrought aluminium alloys for aircraft purposes have recently been issued by the British Engineering Standards Association, 28, Victoria-street, Westminster, S.W. 1. The notes are in the form of leaflets, one of which, numbered M. 18, relates to "Duralumin," and the other, numbered M. 19, to "Y" alloy. General instructions for the use of these materials are given and the methods of annealing, final heat treatment and riveting are explained in detail. The instructions, we notice, are practically identical for both alloys, except that the temperatures are different.

NOTES FROM SOUTH YORKSHIRE.

SHEFFIELD, Wednesday.

Iron and Steel.—There will be no appreciable movement in any of the local industries this week. The bulk of the heavy departments are shut down on holiday account, and others which normally would have resumed, await the result of the engineering ballot. That result will have a great effect on production throughout the South Yorkshire area. From the standpoint of orders the position has steadily improved during the last six weeks. A greater proportion of home and overseas inquiries has resulted in definite contracts, and work which was suspended during the period of high prices has been put into commission; but until the engineer key-men return it is impossible to make headway. Should they decide to return, it will be possible on the strength of new bookings to absorb a considerable percentage of the semi-skilled and labouring element among Sheffield's 50,000 unemployed. The upward movement has at last become manifest in a minor degree in the tool section. Colonial and Dominion markets are keeping closely in touch with revised values. Foreign competition is less severe here than in any other branch. The main obstacle appears to be the maintenance of a ruinous policy of undercutting among home manufacturers. This is mainly due to the apparently endless unloading of Government surpluses, which enables merchants possessing war stocks to get much below the current cost of production. Edge tool manufacture suffers acutely on this account. Home competition in files, saws, and twist drills is particularly severe. Colonial orders for railway axles, tyres and springs are being steadily placed, and home railways are less niggardly in placing contracts for renewals. There is also evidence of more movement in colliery machinery and equipment, and in steel fittings and castings for the automobile and agricultural industries. Businesses supplying requisites for electrical engineering are keeping a close watch on wireless broadcasting developments. Scarcity of new business in the building trade is responsible for an average reduction of 7½ per cent. on fireplaces and light castings. In alloys, tungsten powder has moved up 2*d.* to 1*s.* 8*d.* per pound, but is still below the pre-war level. Sales of special steels are very difficult to negotiate particularly in view of rising tariffs in consuming countries.

South Yorkshire Coal Trade.—Optimistic manufacturers are negotiating for increased supplies in anticipation of improved labour conditions in the early future. Meanwhile shipments of best steams are maintained at a high level, and prices have a firm appearance. In contrast, home gas companies are content with minimum deliveries, while business in best quality house coal has dwindled greatly. Unofficial cuts of from 2*s.* to 5*s.* per ton are reported at individual collieries. It is likely that market quotations will show an early revision downwards. The coke market is almost solely dependent on the export demand for foundry sorts. Quotations:—Best branch handpicked, 38*s.* to 39*s.*; Barnsley best Silkstone, 34*s.* to 36*s.*; Derbyshire best brights, 33*s.* 6*d.* to 34*s.*; Derbyshire best house, 26*s.* to 28*s.*; Derbyshire best large nuts, 24*s.* to 26*s.*; Derbyshire best small nuts, 16*s.* to 18*s.*; Yorkshire hards, 23*s.* to 24*s.*; Derbyshire hards, 21*s.* to 23*s.*; rough slacks, 10*s.* to 12*s.*; nutty, 7*s.* 6*d.* to 8*s.* 6*d.*; smalls, 2*s.* to 4*s.* 6*d.*

THE BERLIN-RHINE TELEPHONE CABLE.—The decision to connect Berlin with the two chief cities of the Rhine, Düsseldorf and Köln, by a direct subterranean telephone cable dates from 1911, but the work had hardly advanced beyond Magdeburg by the beginning of the war, and it was only completed last winter. The straight-line distance from Berlin to either of the two cities is over 300 miles, and the cable is at present probably the longest in Europe. The cable was provided from the outset with Pupin loading coils; recently electronic valves have further been added. The cables are drawn into the tubular conduits of cement blocks in which the lead sheathing of the cable is not specially protected. The conduit is accessible by wells 170 m. apart; every 1·7 km. a larger well is provided, and at distances of 30 km. testing stations have been fitted up. Part of the wires were made in the new mills of the Siemens-Schuckert Werke at Gartenfeld, which were built by Friedrich Krupp, and started supply in January 1920. The actual capacity of the mills is 7·5 tons of wire per hour.

TRACTION CIRCUITS AND TELEGRAPH WIRES.—At the recent International Railway Congress at Rome there was a certain amount of discussion concerning the troublesome interference with telegraph lines which was liable to occur due to the inductive effects of alternating-current traction circuits. In some cases telegraph and telephone wires had to be removed from the neighbourhood of the power conductors in order to avoid interference. Messrs. E. Frattola, V. E. Castelli and R. Regnoni of the Italian State Railway Administration have devised a telegraphic system which is claimed to be immune from interference troubles, and this system is now being tried on certain of the Italian electrified lines. The usual one-wire circuit with earth return is retained, but telegraphing is effected by means of an alternating current having a frequency relatively high to that used for traction. The telegraph receiving apparatus is tuned to respond to the frequency of the message current and remains insensible to currents of lower frequency induced by the presence of the traction system. Frequencies of 126 to 150 periods are used for the telegraphic current, these being sufficiently remote from the frequency of currents used for traction or industrial purposes. A pamphlet describing the apparatus has been forwarded to us by Mr. Enrico Frattola, of 197 via Tritone, Rome.

NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

MIDDLESBROUGH, Wednesday.

The Cleveland Iron Trade.—Holidays this week have caused business to be almost suspended, but a feeling prevails that expansion of trade will quickly follow the end of the disastrous deadlock in the engineering industry. Sales of Cleveland pig-iron to Scotland are still conducted on the basis of 96*s.* 8*d.* f.o.t. Grangemouth for No. 3, but all other home and foreign transactions are on the usual terms of f.o.t. makers' works or f.o.b. Tees, and quotations stand:—No. 1 and siliceous iron, 95*s.*; No. 3 G.M.B., 90*s.*; No. 4 foundry, 87*s.* 6*d.*; No. 4 forge, 85*s.*; and mottled and white, 80*s.*

Hematite.—Notwithstanding curtailment of production, output of East Coast hematite is more than sufficient for current needs, but with prospect of consuming works being busier in the near future, the make promises to be fully taken up. Nos. 1, 2 and 3 are 96*s.* for home purposes, and 95*s.* for export.

Foreign Ore.—New business in foreign ore is on an extremely limited scale, but heavy imports are overtaking arrears of deliveries, so that demand should improve. Best rubio is 27*s.* c.i.f. Tees, and good Mediterranean ores are 23*s.* 6*d.* c.i.f. Tees.

Coke.—Blast-furnace coke is falling in value. Average Durham qualities are now on sale at 27*s.* delivered, and some local consumers report that they can purchase at less.

Manufactured Iron and Steel.—Extreme quietness still characterises nearly all branches of finished iron and steel, but hope is now entertained that the worst of the depression has been experienced, and that a fair number of orders that have been held up by the deadlock in engineering will be released. Business on export account can still be put through at substantially below the following rates to which manufacturers adhere for home trade:—Common iron bars, 12*l.*; iron rivets, 14*l.*; steel billets (soft), 7*l.* 10*s.*; steel billets (medium), 8*l.* 5*s.*; steel billets (hard), 8*l.* 15*s.*; steel boiler plates, 14*l.* 10*s.*; steel ship, bridge and tank plates, 10*l.* 10*s.*; steel angles, 10*l.*; steel joists, 10*l.* 10*s.*; heavy sections of steel rails, 9*l.* 10*s.*; fish plates, 14*l.* 10*s.*; black sheets, 12*l.*; and galvanised corrugated sheets (24-in. gauge, in bundles), 15*l.* 15*s.*

Shipments of Iron and Steel.—The May shipments of iron and steel from Middlesbrough, together with 2,780 tons of pig-iron from the neighbouring port of Skinningrove totalled 79,389 tons, composed of 40,991 tons of pig-iron, 10,829 tons of manufactured iron, and 27,560 tons of steel. For the previous month the total clearances of iron and steel reached 86,902 tons. Of the pig-iron shipped during May, 27,371 tons went to foreign ports, and 13,620 tons coastwise; of the manufactured iron despatched 10,511 tons went to foreign ports, and 318 tons coastwise; and of the steel cleared 22,546 tons went to foreign ports, and 5,014 tons coastwise. The principal receivers of pig-iron were:—United States, 8,900 tons; Wales, 7,820 tons; Belgium, 3,449 tons; France, 2,985 tons; Germany, 2,811 tons; Italy, 2,764 tons; Scotland, 2,385 tons; Denmark, 1,452 tons; and Finland, 1,150 tons. As usual India was the largest customer for both manufactured iron and steel, taking 9,901 tons of the former, and 10,975 tons of the latter. Among the other principal receivers of steel were:—China, 1,487 tons; Straits Settlements, 1,453 tons; Siam, 1,052 tons; South Australia, 1,008 tons; and Victoria, 1,005 tons.

Ironworkers' Wages.—The accountants to the Board of Conciliation and Arbitration for the Manufactured Iron and Steel Trade of the North of England having certified the average net selling price of bars and angles for the two months ending April 30, at 11*l.* 5*s.* 10·24*d.* per ton, as compared with 11*l.* 16*s.* 10·05*d.* per ton for the previous two months, under sliding scale arrangements, puddling and other forge and mill wages are reduced by 5 per cent. for the months of June and July.

ALUMINIUM TUBES FOR AIRCRAFT CONSTRUCTION.—Publication No. 2 T. 9. of the British Engineering Standards Association relates to aluminium tubes for aircraft purposes, and cancels the Admiralty Air Department's Specification T. 9. The specification covers the quality of the material, the dimensions and tolerances for standard tubes up to 3 in. in diameter, mechanical tests, and the procedure in connection with inspection; it is intended in fact, to include all the technical provisions necessary for the supply of the material referred to. The address of the association, from which copies of the publication can be obtained, is 28, Victoria-street, Westminster, S.W. 1.

AIRCRAFT DOPE AND PROTECTIVE COVERING.—A revised edition of the British Engineering Standards Association's "British Standard of Reference for Aircraft Dope and Protective Covering," is issued in publication No. 83, and provides a standard of reference reproducible in any laboratory, so as to enable a satisfactory comparison to be made of various commercial dopes. The pamphlet includes formulæ for reference dope, "Raftite" solvent and for reference protective covering with complete specifications for the ingredients used for making these solutions. In appendices the standard distillation apparatus and the method of using is described, and the method of applying the dope and protective covering is explained in detail. The price of the publication is 1*s.* net, or 1*s.* 2*d.* post free, and it can be obtained from any bookseller or from the offices of the association at 28, Victoria-street, S.W. 1. It is published for the association by Messrs. Crosby Lockwood and Son, 7, Stationers' Hall-court, E.C. 4.

NOTES FROM THE NORTH.

GLASGOW, Wednesday.

Scottish Steel Trade.—The outlook in the Scottish steel trade is much more hopeful with so many union men returning to their various employments this week, and the prospect of the Amalgamated Engineering Union men also coming to terms with their employers in the near future. Meantime work in the steel works is still very unsatisfactory and no distance ahead can be seen, but managements anticipate a gradually improving demand for general material as the various branches of the engineering industries absorb their men. Inquiries have been increasing of late, but little booking has resulted so far. The export trade is not good, but inquiries for shipment lots are coming in more frequently, and that would indicate that foreign buyers are very likely to come into the market as actual purchasers at no distant date when conditions here become a little more normal. Black steel sheet makers report no improvement in the demand either on home or export account, and the various works are doing very badly at present. Foreign inquiries are fair, but little business is following, and it would seem that the foreigner is just feeling the pulse of the market still, and, having held off so long now he considers that by waiting a little longer he will be able to place his orders on more advantageous terms shortly. Prices show no alteration this week, but one would not be surprised if the steel makers at their meeting at the end of the week decide to lower their quotations. Two reasons are being advanced by those in favour of a cut, firstly the increasing competition from the Continent and secondly that easier prices will bring out fresh business.

Malleable Iron Trade.—No change can be reported in the malleable iron trade of the West of Scotland, but home buying may take a turn for the better now that the labour dispute is nearly over. Orders for export are small and not very remunerative. Employment is very bad, as only a few shifts per week is the general run in the district. The price of "crown" bars is unchanged at 11*l.* per ton delivered Glasgow.

Scottish Pig-Iron Trade.—A rather better tone is prevailing in the Scottish pig-iron trade this week, but movement is still very restricted, and the present output continues to be more than ample to meet all demands. The prospect of some improvement at the steel works will lead to a little demand for hematite, and that cannot come along too soon. With the men (all who can actually be absorbed at present) of the 45 unions which have accepted the offer of the Engineering Employers' Federation back at work now business will gradually get better, and the demand for all kinds of iron will increase. At the moment, moreover, there are indications of an improved shipping demand, which will certainly ease the situation. Prices are as follow:—Hematite, 5*l.* 5*s.* per ton, delivered steel works; foundry iron, No. 1, 4*l.* 18*s.* per ton; and No. 3, 4*l.* 13*s.* per ton, at producers' works.

GRAVING DOCK AT DURBAN.—In connection with the new graving dock which is being constructed at Durban by the Department of Harbours and Railways, the High Commissioner for the Union of South Africa has placed with Sir W. G. Armstrong, Whitworth and Co. the contract for the supply and erection at Durban of two caissons for closing the inner and outer entrances of the dock, with the hauling machinery, complete. The caissons will be of the rolling "box" type, the outer entrance being 110 ft. wide by 47 ft. deep, while the inner entrance will be 110 ft. wide by 49 ft. deep. The outer caissons will carry vehicular traffic, while the inner caissons will take pedestrian traffic only. In each case the hauling machinery will be electric.

BIRTHDAY HONOURS.—Among the honours conferred by H.M. the King on the occasion of his birthday this year there are but few that have been bestowed upon members of the engineering profession and industry. Baronetcies have been given to Lieut.-Colonel Sir John Norton-Griffiths, K.C.B., D.S.O., M.P., late Lieut.-Colonel of the 2nd King Edward's Horse, who rendered valuable services during the war; upon Mr. Edmund Nuttall, A.M.Inst.C.E., who is head of the firm of Nuttall and Co., of Manchester, and who has been connected with many important engineering works; and upon Mr. George Sutton, M.I.E.E., Chairman and Managing Director of Henley's Telegraph Works, and one of the founders and a past-Chairman of the Cable Makers' Association. The honour of knighthood has been conferred upon Mr. Edwin Airey, Governing Director of William Airey and Son, Engineers and Contractors; upon Lieut.-Colonel Alan Hughes Burgoyne, M.P., who has always taken a deep interest in naval matters; upon Major Collingwood George Clements Hamilton, M.P., an engineer by profession, who in 1917 was Director of Enrolment, National Service, and in 1919–20 was Parliamentary Private Secretary to the Minister of Pensions; upon Mr. Ernest Montague Hughman, late of Pyne, Hughman and Co., Engineers and Shipbuilders, who is a member of the Council of the Institution of Engineers in India and Hon. Secretary of the Indian Council of the English Institution of Electrical Engineers; upon Mr. Edward Mauger Iliffe, C.B.E., director of Iliffe and Sons, publishers, and Controller of the Machine Tool Department of the Ministry of Munitions; and Mr. William Mills, who, in addition to being a member of the Imperial Mineral Resources Bureau, is the inventor of the Mills hand grenade so extensively employed throughout the war. A Companionship of the Order of St. Michael and St. George has been conferred upon Mr. William Herbert Barrett, Assistant General Manager of Railways and Harbours, Union of South Africa.

NOTES FROM THE SOUTH-WEST.

CARDIFF, Wednesday.

The Coal Trade.—The trading results of the South Wales coal trade for April was worse than in any other month, with one exception, since the termination of the national strike. The surplus profits, according to the certificate of the joint accountants, amounted to only 13,144*l.*, and the industry can only afford to pay in June 7·37 per cent. above the 1915 standard rates. The minimum under the national agreement is, however, 28 per cent., and this has to be made up by the owners sacrificing their standard profits, their share of the surplus profits and by finding 36,000*l.* The surrender of the standard profits involves a sum of 280,354*l.*, so that the total loss to the owners is 316,684*l.* This unsatisfactory result was brought about by a loss in production in April, caused by holidays, and an increase in the cost of production. In April there were only 23 working days, compared with 27 in March, while snowstorms at the beginning of the month also interfered with the output, which was 800,000 tons less than in March. This heavy reduction was accompanied by an increase in the cost of production of 1*s.* per ton, 10*d.* of which was for costs other than wages, and 2*d.* for labour. At the same time selling prices were practically the same as in March. The unsatisfactory result of the April audit is illustrated by the following table showing the audits for the six months ending April:—

1921.	Certified Wage Rate. Per Cent.	Surplus Proceeds. £	Profits Sacrificed. £
November ...	12·11	109,949	247,000
December ...	6·99	6,538	343,000
1922.			
January	11·00	85,000	262,000
February ...	9·13	46,043	284,000
March	16·76	227,837	171,371
April	7·37	13,144	316,684

Meanwhile conditions on the coal market are none too bright. The foreign demand is quiet, and though the miners were given three days holiday for Whitsun the loss in production has not improved the state of the market. Best Admiralty large coal is obtainable at 26*s.* 6*d.* to 27*s.*, compared with 28*s.* 6*d.* a fortnight ago, while best Monmouthshire large is available round 26*s.* 6*d.*, and at these prices buyers continue to hold off. The position is rendered more awkward by the fact that the miners' representatives have intimated to the owners that the men are not prepared to work for all time for the present wages, which, they state, after taking into consideration the cost of living, are "starvation" wages. Foreign exports as cargo in the past week amounted to 544,000 tons, or 23,000 tons more than in the previous week. Of this total 152,000 tons were despatched to France, 110,000 tons to South America and 79,000 tons to Italy.

DECREASE IN MAJOR DISASTERS IN AMERICAN COAL MINES.—It is estimated by the United States Bureau of Mines that approximately 750,000 men were engaged in coal-mining in the United States in 1921. The figure shows a loss of 30,000 employees from the preceding year, when probably 780,000 men were employed in the industry. The quantity of coal produced in 1921 represents approximately 251,000 tons for each life lost. Although this figure does not compare favourably with that for the preceding year, it has been surpassed in only three years—1916, 1918 and 1920. Approximately 144,000,000 shifts were worked by all employees in 1921, whereas 188,000,000 shifts were worked in 1920. On this basis the fatality rate per thousand full-time or 300-day workers was 4·11 in 1921 as against 3·62 in 1920. A gratifying feature of the year's operations was the small number of major disasters and of deaths resulting therefrom. There were but five accidents resulting in five or more deaths each, and the total number of deaths from such accidents was only 34, this number being smaller than for any preceding year since annual statistics of coal-mine fatalities have been published by the Federal Government (first year, 1911), and also constituting only 1·7 per cent. of the 1,973 fatalities from all causes combined, a percentage also lower than for any previous year during the same period.

PROBLEMS OF THE CANNING INDUSTRY.—The food-canning industry has to fight many justified suspicions and unjustified prejudices. To meet these the National Canners' Association of Washington, D.C., have established a research laboratory. According to the director of this laboratory, Mr. W. D. Bigelow, there is no type of food poisoning peculiar to canned food. Many cases of so-called ptomaine-poisoning have been traced down by Gaertner and by Rosenau to bacteria which are harmless when taken by the mouth and which would not survive the heat of canning processes. The indispensable vitamins are said to be destroyed by heat, but this applies at temperatures reached in boiling vegetables, and authorities differ as to the parts played by the heat and by the oxygen. In canning processes sterilisation at 80 deg. C. is often considered sufficient, if continued for many hours; 80 minutes at 121 deg. C. are regarded as ample for peas and corn. Slight discoloration of foods, by traces of sulphuretted hydrogen liberated from proteins or by iron are harmless, but may depreciate an article badly. Hard water may make the food tough. The suitability of a tinplate is best ascertained by trial; steel plate for canning should be pure, and contain not more than the following percentages:—carbon 0·2, sulphur 0·05, silicon 0·025, phosphorus 0·1, but this high purity is probably unnecessary in many cases.

NOTICES OF MEETINGS.

THE NORTH OF ENGLAND INSTITUTE OF MINING AND MECHANICAL ENGINEERS.—Saturday, June 10, at 2 p.m., in the Lecture Theatre of the Institute, Newcastle-on-Tyne. General Meeting. The following papers will be read and discussed: "The Limestone Coal Reserve of North Northumberland." by Mr. R. C. Carruthers, F.G.S.; "The Development of Metal Supports for Mines," by Mr. John Roberts, D.I.C.

THE MINING INSTITUTE OF SCOTLAND.—Saturday June 10, at 3 p.m., at the Heriot Watt College, Chambers-street, Edinburgh. General Meeting. Papers to be discussed: "The Operation of Mines in Parallel," by Mr. Joseph Parker, B.Sc.; "Pipe Friction and Pump Efficiency," by Mr. William Brazenall; "The Characteristic Curves of Fans and Their Application to Predetermine the Output and Efficiency of Fans Working Singly and in Parallel on Various Resistances," by Mr. Joseph Parker, B.Sc.; "Resistance to Traction of Mine Tubs," by Mr. John Wilson.

THE INSTITUTION OF MECHANICAL ENGINEERS.—Summer Meeting. Paris, June 12 to 17. At the Meeting Hall of the Société des Ingénieurs Civils de France. The following papers will be read and discussed: "Feed Water Heaters for Locomotives," by Professor Edouard Sauvage; "Electric Locomotives," by Sir Vincent L. Raven, K.B.E.; "Mechanical Vehicles and Road Surfaces," by Brigadier-General Lord Montagu of Beaulieu, K.C.I.E., C.S.I.; "The Use of the Turbo-Compressor for Attaining the Greatest Possible Speeds in Aviation," by Professor Auguste Rateau; "The supersaturated Condition as shown by Noozle Flow," by Professor A. L. Mellanby, D.Sc., and Mr. William Kerr; "Air Compressors," by Mr. William Reavell; "The Effect of Temperature on Some of the Properties of Metals," by Professor F. C. Lea, O.B.E., D.Sc. Wednesday evening, June 14, at 8.30 p.m.: Lecture, "Recent Photo-Elastic Researches on Engineering Problems," by Professor E. G. Coker, D.Sc., F.R.S. Thursday evening, June 15, at 7.30 p.m.: Institution Dinner in the Hotel Continental. Visits to various works—Liége, June 18 to 21. Official Opening by His Majesty the King of the Belgians of the Liége International Scientific Exhibition. Meetings of the International Scientific Congress. Visits to various works.

THE IRON AND STEEL INSTITUTE.—Tuesday, June 13, at 3 p.m., in the Mappin Hall, Sheffield University. Further discussion of paper, "British Siemens Furnace Practice," by Mr. Fred. Clements.

ELECTRIFICATION OF THE GOTTHARD RAILWAY.—On Sunday, May 28, the first electric train from Goldau arrived in Luzern. Electric traction was thus introduced on the last section of the Gotthard Railway, and the work of the electrification of the whole line, Chiasso-Luzern, was completed. The total distance is 225 km. (140 miles). It is interesting to note that, just forty years previous, the main line of the Gotthard Railway was opened on June 1, 1882, and that twenty-five years previous, again on June 1, the branches Immensee-Luzern and Goldau-Zug were ready for service. The electrification work of the Gotthard Railway was begun in 1913, and carried out under the direction of the engineers A. Schrall and E. Huber-Stockar. Much delayed by the war, the work involved a good deal more than the electrification alone would have required. Some of the bridges and viaducts had to be strengthened and rebuilt, and the creation of the Lake Ritom hydroelectric power station, which feeds the line, offered exceptional difficulties, to which we have referred on various occasions. In a few months, when the turbines in the Amstey power station, the second electricity supply source, will have been installed, the electric service will be extended to the Luzern-Basel line.

VULCANISED FIBRE.—The Board of Trade give notice that they have received a complaint by the British Electrical and Allied Manufacturers' Association that vulcanised fibre manufactured in the United States of America is being sold or offered for sale in the United Kingdom at prices below the cost of production thereof as defined by the Safeguarding of Industries Act, 1921, and that by reason thereof employment in the vulcanised fibre industry in the United Kingdom is being, or is likely to be seriously affected. The Board of Trade, in exercise of the powers conferred upon them by Part II of the Safeguarding of Industries Act, 1921, have referred the matter for inquiry to a committee constituted for the purposes of that part of the Act, and consisting of Sir Bernard Mallet, K.C.B. (chairman); Mr. J. Arthur Aiton, C.B.E.; Sir John N. Barran, Bart.; Mr. G. A. Moore; and Mr. Arthur Pugh. The committee are directed, after ascertaining the facts, to report to the President of the Board of Trade: (*a*) Whether the conditions specified in Section 2, Sub-section (1) of the Safeguarding of Industries Act, 1921, are fulfilled; (*b*) on the effect which the imposition of a duty under Part II of the Act on goods of the class or description covered by the complaint would exert on employment in any other industry being an industry using goods of that class or description as material; and (*c*) whether in the opinion of the committee production in the industry manufacturing similar goods in the United Kingdom is being carried on with reasonable efficiency and economy. The committee propose to hold their first sitting for the taking of evidence at 11 a.m. on Tuesday, June 20, 1922, at 5, Old Palace Yard, Westminster, London, S.W. 1. The secretary of the committee is Mr. W. W. Hobson, Board of Trade, Great George-street, London, S.W. 1, to whom all communications should be addressed.

THE LEVALLOIS WORKS OF THE HOTCHKISS COMPANY.

(*For Description, see page* 710.)

FIG. 5. VIEW IN TURNING BAYS.

FIG. 6. VIEW IN MILLING BAYS.

THE ANDRÉ CITROËN WORKS, QUAI DE JAVEL, PARIS.

(*For Description, see Page* 705.)

(*To face page* 706.)

FIG. 2. CHASSIS FRAME PLATE FLANGING.

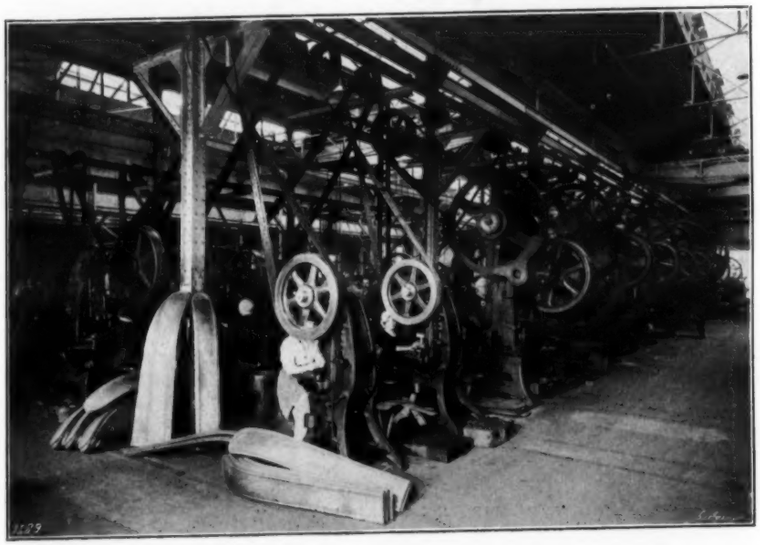


FIG. 3. STAMPING PRESSES.

FIG. 4. HEAT TREATMENT FURNACES AND PLANT.

FIG. 5. VIEW IN FOUNDRY.

THE ANDRÉ CITROËN WORKS, QUAI DE JAVEL, PARIS.

(*For Description see Page* 705.)

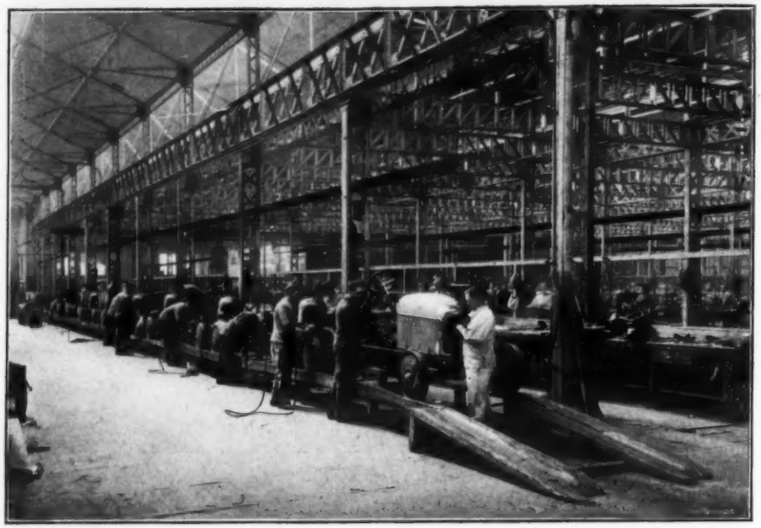


FIG. 6. CHASSIS ERECTING SHOP.

FIG. 7. CHASSIS INSPECTION DEPARTMENT.

FIG. 8. MOTOR CAR BODY FRAME WORK.

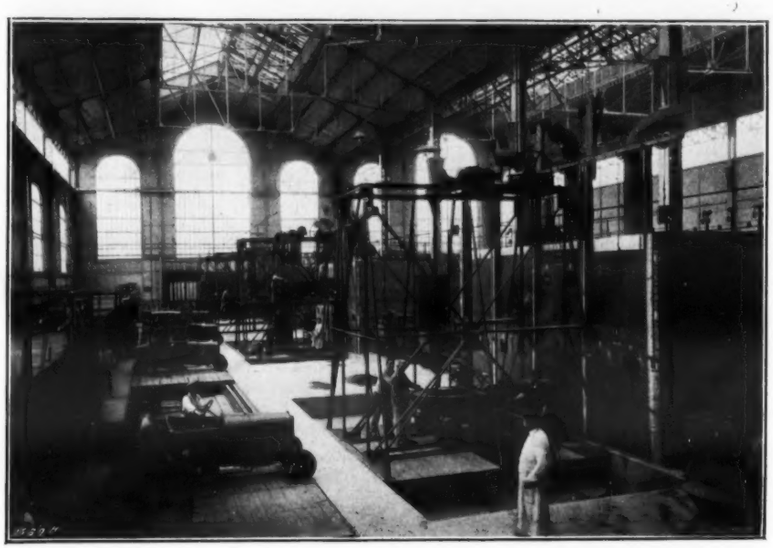


FIG. 9. PAINTING AND DRYING PLANTS.

(*To face page* 707.)

THE WORKS OF THE NORD-PARIS COMPANY.

(*For Description, see Page* 708.)

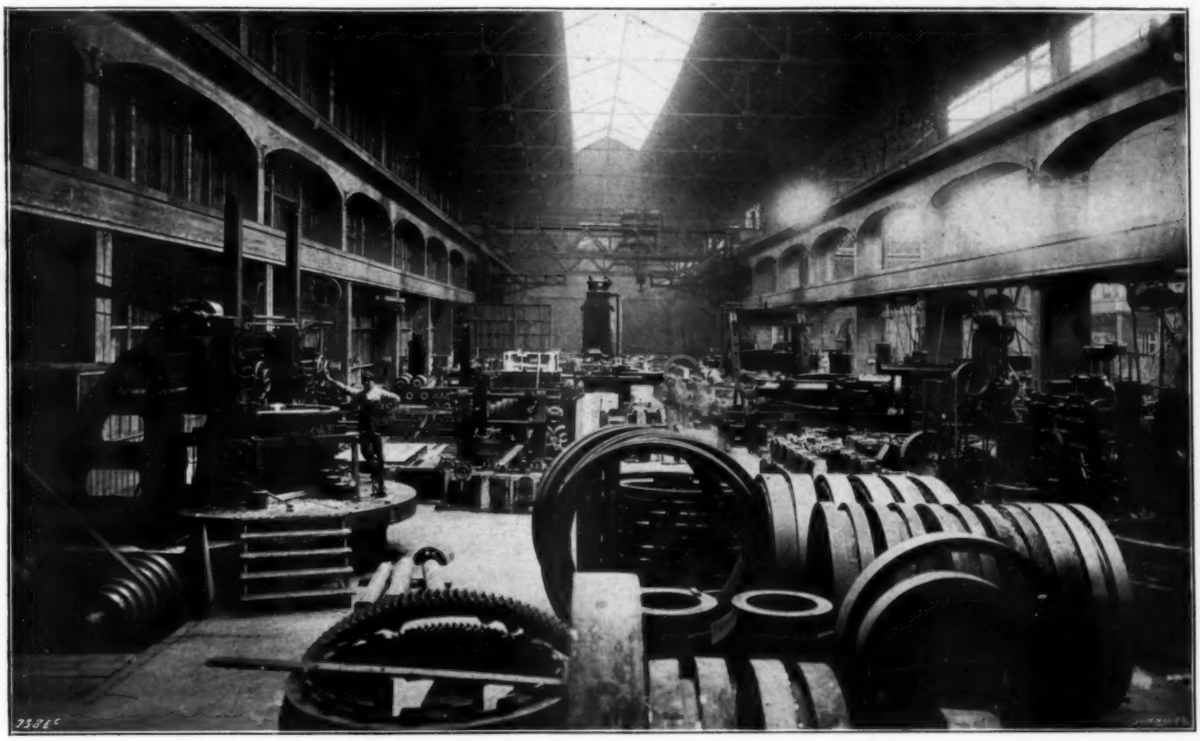


FIG. 3. VIEW IN HEAVY MACHINE SHOP.

FIG. 4. VIEW IN HEAVY MACHINE SHOP.

(*To face page* 708.)

THE WORKS OF THE NORD-PARIS COMPANY.

(*For Description, see Page* 708.)

FIG. 5. VIEW IN SMALL MACHINE SHOP.

FIG. 6. VIEW IN SMALL MACHINE SHOP.

(*To face page* 709.)

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ENGINEERING.

FRIDAY, JUNE 9, 1922.

RAILWAY ECONOMIES.

FOR the reason that their successful operation involves so much real engineering we have always given considerable prominence to matters affecting the railways of this country. Doubtless the same connection prompted Sir Eric Geddes to take as his subject for the Canet Lecture delivered before the Junior Institution of Engineers on Thursday, the 1st inst., the Railway Act of 1921. Having been responsible for the Bill, and for its passage through Parliament, no one could very well be better able to give an exposition of its intentions. Beyond some cursory references to general matters, Sir Eric quite appropriately, in view of the audience to whom he was addressing himself, paid most attention to points of an engineering nature on which the changed conditions will have a very material effect.

There is a common saying that there is wisdom in many counsellors. But if we go back to the original in the Book of Proverbs the reading will be found to be "In the multitude of counsellors there is safety," which savours much more of caution than of action. It is, in fact, the general experience that the more there are in general consultation the less definite is the action taken. The recent railway congress at Rome is a case in point, although in that particular instance there were complications of language and of schools differing more widely in thought and practice than usual; but the fact was clearly evident that while agreement could be reached on lines so broad as to be of little practical value, anything of the kind on practical and constructive detail was very difficult to arrive at. Both biblical and secular history, as a matter of fact, justify the idea that if there are things to be achieved in the world they are best left for their actual accomplishment to one man, or at the most a few. It is the small committees which get through the most work, and through which most of the real progress is made, and for this reason there is hope that in the new railway era we shall see decisions arrived at on questions on which it has hitherto been difficult either to obtain agreement, or action.

This aspect Sir Eric made one of the chief points of his address. The amalgamations which have taken, are, or will be, taking place, will have the effect of placing technical decisions in the hands of a few able men, instead of, as hitherto, the actions of men of the front rank being hampered by the reluctance or inability of others to commit themselves. A practical solution is clearly more possible between four really capable men, than between the representatives of some 120 systems—and, it may be added, since each group will be a large organisation, and each chief may be expected to work for uniformity on his own system, even if co-operation with others cannot be pushed very far at first. Thus, in any case we shall have a fairer prospect of getting things done, for the policy and force of one man invested with large powers will replace the many, some of whom in the past even when willing, have lacked the means. This idea, must, however, not be pushed too far, for the 120 systems referred to by Sir Eric Geddes range all the way from separate systems to small concerns operated by larger companies and having little more in the way of staff than that at their registered offices.

It is, of course, early yet to discuss the ultimate organisation of the big groups, but it would appear reasonable to expect that in the future these large undertakings will each have something in the way of general headquarters which will decide broad lines of policy and such matters as standardisation, while actual operation will be rather more decentralised, each group being divided up into a number of subsystems of workable size, which may, or may not, resemble the old companies in field of operations or organisation. The headquarters would include the chief technical and other officials, with a staff adequate to deal with such problems as would pass up to them, to maintain uniformity of policy over the whole. Naturally the sub-systems would be as large as would be economical; smaller shops, &c., would be suppressed and concentrated, and so on. In this way it would be possible to work towards standardisation, and, by avoiding overburdening the highest technical staff with too much executive detail, would enable full attention to be devoted to the questions to be settled and the relative merits of different solutions.

At the best, as Sir Eric pointed out, results will be slow of realisation. Everyone who has attempted anything in the way of standardisation on railways, especially where British practice prevails, is aware how painfully long a time it takes to make a noticeable impression on the whole field. An engineer's professional lifetime is hardly sufficient for the change unless it be accelerated in some way. If standardisation be based on normal replacements it may be forty years before the older types of locomotives are eliminated, by which time probably new conditions will have arisen requiring new standards, so that while it might be possible to work all the traffic of this country by eight or ten classes of locomotives, the actual number of types could never possibly be reduced to anything like that figure. In addition to standard classes a large number of parts may be taken in hand, and standards thus introduced by degrees into the older types, but the years when these fall in for renewal are really very slow in coming round, and there is often very little actually to show for a great deal of work and thought. Some years may be cut off the life of a remainder if information is available to show that the cost of upkeep or working of those still surviving is abnormal.

Going back a good many years we may refer to a rather extreme example. A railway of standard gauge was run in such a way that when its locomotive stock had increased to about 200 it had 54 different types in service. At one period of development the average number of locomotives per class was no larger than 1·8, while the classes increased at the rate of 3·25 per annum. In a subsequent period of about twenty-five years, when standardisation was carefully worked out, the stock increased to nearly 500, while the number of classes requiring regular repairs was reduced to 22, with, in addition, a few exceptional machines for very special work. Standards were worked out in such a way as to group, for the purposes of repair

parts many of the old classes with the new stock. In one instance no less than seven old classes were grouped into one for renewable parts, and these in many items conformed to the seven standard classes for new stock. From the earlier chaos a state was gradually evolved in which, with more than twice the stock, including new and old, 50 per cent. of the engines had only three types of cylinders between them, 69 per cent. of the stock had standard valves and about the same number standard motion, while a much larger proportion had standard cranks and big-ends. If a few survivals of over forty years of age were eliminated, the above figures would be still more favourable—but, as the limit of the old engines and rebuilds was reached, conditions had become such that the seven standard classes no longer sufficed for the traffic, and more powerful engines had to be introduced. The number of classes consequently increased again, even before the old standards had completely leavened the whole. This will always remain likely if the world is to progress, but is no reason for abandoning a wise standardisation policy as hopeless of consummation.

In another direction on the railways economy will clearly be possible. Many towns are served by several railways, which, in some cases, will now be in the same group. Obviously, operation will be simplified, and better value obtained from the property by reorganising working, possibly to the closing down of certain stations, or goods or marshalling yards. Ultimately it may prove feasible to retrieve some of the capital invested in the property no longer of service to the railway. Such changes as these will be as slow as those referred to above. It must take time to decide what is best in each case, to effect the necessary alterations, provide physical connections or add to the central accommodation. Expense will also be involved, and the various plans will have to be realised by degrees. Some economies of this character were introduced before the war, but at that time the railways were being forced, by the trend of public policy, such as the refusal to allow them to combine, into a system of pooling from which Sir Eric Geddes claims the Act of 1921 has now saved the country. In the pooling then being introduced any company introducing improvements only reaped a portion of the resulting benefit, with the result that development would ultimately have been stultified. Of such a condition we are certainly well rid.

There are, of course, obvious difficulties ahead. Most railway officials agree on the question of larger wagons, but before larger units are in regular service two important questions require settlement, namely, brakes and couplings. If power brakes become possible through the adoption of some form of tight coupling, the choice of system will have to be made, as dual fitting on freight stock is prohibitive. These and other problems which we inherit will give the reduced number of chief officials plenty to think about when all the questions of organisation, &c., have been settled, but, with Sir Eric, we may reasonably look for more expeditious concerted action now, all things considered, than was probable, or possible, formerly.

PROBLEMS FOR UNITED STATES SHIPOWNERS.

WHEN it is remembered that while in most maritime nations the development of merchant shipping has been gradual and has followed the natural expansion of trade, it is not particularly surprising that numerous problems have arisen in connection with the suddenly created merchant marine of the United States. The gross register tonnage of the American merchant navy has grown from 8,871,000 tons in 1917 to 18,282,000 tons in 1921, and the whole of the additional tonnage consists of ships designed for international commerce, of which American owners and managers have had but little experience. Excellent organisations, however, are now working which will help to supply this deficiency, and much may be done by a nation possessing the energy and determination of the Americans, to remove or surmount the other obstacles which still hamper the establishment of a great American mercantile marine.

The success or failure of American efforts in this direction has naturally a considerable interest, not only to the shipping community in this country, but to the nation in general, and for this reason it may be worth while to consider how the problem is regarded in the United States, and what steps it is proposed to take there towards its solution. We have already dealt, on page 794 of our last volume, with some aspects of the problem as presented in a number of papers read before the Society of Naval Architects and Marine Engineers in November last, and we now propose to refer briefly to another communication to the same body read by Mr. Eugene E. O'Donnell at a special meeting of the Society held in New York on the 19th ultimo.

The author, who is a manager of cargo steamers engaged in both the coastwise and overseas trades, first points out that, as a whole, the American merchant marine is by no means well adapted to the particular requirements of the nation. The new fleet, built mainly for war purposes, contains, he says, far too great a proportion of slow-speed "tramp" steamers, and lacks not only fast passenger vessels but also cargo steamers of the liner type. Another handicap referred to is the payment for wages and subsistence of the crews of American vessels on a higher scale than is paid by European or by Japanese shipowners. American shipboard wages are put at from 30 per cent. to 40 per cent. above the British scale, and the latter at some 15 per cent. above the Scandinavian scale. The author, and the majority of American owners and shippers, regard State assistance as the only possible means of reducing this particular handicap.

An important point in this connection is the relative efficiencies of the crews, and the author admits that, on the average, the efficiency of American officers and men, due to less experience, is lower than that of their European rivals, although he believes the disparity is rapidly lessening. This seems to be one of the greatest difficulties confronting the American shipowner. Time, as the author rightly remarks, is the only possible remedy, and to us it appears likely to require several years to train officers and men in sufficient numbers to man the new American fleet efficiently. The master of a tramp steamer, for instance, requires considerably more than a knowledge of navigation and seamanship in order to work his ship to the best advantage of the owners, and it is largely in the necessary business training and experience in commerce in distant foreign ports that many American masters are, at present, lacking.

The question of manning schedules, in which the author claims that foreign competitors have some advantage over American owners, does not appear to us to be very material, at least in comparing British and American ships. Mr. O'Donnell, in fact, acknowledges that most British ocean-going ships engaged in foreign trade carry as many certificated deck officers, and frequently as many engineers, as do American ships, but states that British legislation relating to this and other similar matters is generally less stringent than American.

National assistance, in the form of beneficent legislation and subsidies, such as has been recommended to Congress by the American Steamship Owners' Association and the United States Ship Operators' Association, the author regards as a *sine qua non* to the successful development of the American merchant marine. In the first place, he recommends that a shipping subsidy law should not require a proportion of more than 40 per cent. of American citizens among the deck and engine staffs of American ships. The present proportion, as indicated by the returns of the shipping commissioners, is about 55 per cent., but the author remarks that it would be difficult to maintain the required percentage in foreign ports owing to the inducements to American seamen to desert. Why this should be so, however, is by no means easy to understand if American crews are considerably better paid and somewhat less efficient than those of foreign vessels.

As a further indication of what should be done to improve the existing state of affairs, the author summarises the report of the Navigation Laws Committee, which has recently been issued to the public by the United States Shipping Board. In the first place, the committee recommends that existing American navigation laws, which are at present scattered through numerous volumes of statutes and regulations, with many amendments and clauses repealing Acts and parts of Acts, should be recoded into a single Shipping Act similar to the British Merchant Shipping Act, and, further, that responsibility for the enforcement of the law should be consolidated in a single department resembling the British Board of Trade. With regard to the steamboat inspection laws, the committee find that these should be made more elastic to enable administrative officers to use discretion as to their enforcement. The existing law, it is pointed out, is too general in character and does not give due consideration to the varied types of vessels engaged in different kinds of navigation, thus being difficult to apply and imposing what are regarded as unjust burdens on American shipowners.

As an example of these, it is mentioned that boilers of American vessels are required to be tested annually by hydraulic pressure to one and a half times the working pressure allowed, whereas the classification societies, the British Board of Trade, and maritime governments generally, only require the test to be applied at the original inspection of the boilers and thereafter at the surveyor's discretion; usually it is only applied at the survey period which occurs about once in four years. The annual inspection of the hulls of American cargo vessels is also regarded as an unnecessary burden on owners, in that it involves a loss of from one to three days, according to the size of the ship. It is suggested that passenger vessels should be subjected to this inspection annually, except as regards the hydraulic test of the boilers, and that life-saving equipment of all vessels should be inspected annually. The hulls of cargo vessels, however, should only be inspected at the survey periods, *i.e.*, once in every three or four years. Furthermore, it should not be necessary for vessels to return to an American port for the periodical inspections, which should be carried out by representatives of the Bureau of Shipping located in various foreign ports. This examination would extend the life of the certificate of inspection until the vessel's first arrival at an American port. Various modifications to the Seamen's Act are suggested, as well as the introduction of the continuous discharge book in which a record of the conduct and efficiency of seamen is kept.

Finally, the author remarks that it is highly desirable for the Government to abandon the ownership and operation of vessels and to place the essential services in the hands of private owners and managers at the earliest possible moment. National aid, however, is considered to be essential for the operation of the Government ships after they have passed into private hands. The prompt passage of President Harding's Shipping Bill, Mr. O'Donnell regards as vital to the success of the American shipping industry in the overseas trade. This measure, it will be remembered, besides offering substantial direct aid in the form of compensations and subsidies to both cargo ships and mail ships, proposes that 50 per cent. of the immigrants to the United States shall be carried in American ships. A deduction from the income tax of shippers of 5 per cent. of the freight paid on goods exported or imported in American vessels is also proposed, as well as exemptions of the net earnings of American ships in the foreign trade from Federal taxation, provided that the amount exempted is employed for the purchase or construction of new ships.

Other forms of indirect assistance are provided for, and while the importance of all this help must not be under-rated, we agree with the author that it will not, of itself, suffice to ensure success. American shipowners and managers are fully aware that future prosperity is dependent upon securing a considerable part of the trade now carried in foreign bottoms. They also realise that to do this, even with State aid, their ships must be operated with the utmost enterprise and economy. Experience, and the necessary national characteristics, are also essential to the development of overseas shipping under modern conditions of world trade, and these, we think, will prove to be valuable assets to the British shipping industry in meeting the keen competition to be anticipated in the future.

THE MOUNT WILSON OBSERVATORY REPORT.

THE report of Professor G. E. Hale, the director of the Mount Wilson Observatory, Cal., grows longer every year, and as investigations progress towards completion, necessarily richer and more interesting, but only a few gleanings can be made from this abundant harvest. The opening paragraphs remind us of the accelerated rapidity with which stellar distances are measured. It is nearly ninety years since Bessel measured the distance of a fixed star, and in sixty years, by following the same laborious methods, the distances of an equal number of stars were included in our catalogues. In this century, following the process which Henderson and Bessel inaugurated, some 1,400 have been added. In the last five years, however, by the new and beautiful process of comparing the relative intensities of two lines on a stellar spectrum photograph, at Mount Wilson alone, the parallaxes of 2,000 stars have been estimated. If this work concluded by simply registering the distance of so many stars from the Sun, it would matter little whether 20 or 2,000 were measured, but the knowledge acquired enables us to penetrate some way into the riddle of the stellar cosmos, and grasp the plan of the structure and the mode of evolution of the stars. In their early, or giant, stage, the stars are shown to be immensely inflated gaseous masses, so tenuous that their density may be as low as one-thousandth of that of the Earth atmosphere. This view, at variance it may be with generally-received opinion, is amply confirmed by recent observations with the interferometer, already described in these columns. Antares, for example, is found to have a diameter of 400,000,000 miles. As the stars condense, their temperature rises and their colour changes from red to yellow, and thence to white, marking a turning point in their history. Shrinkage follows, Arcturus has shrunk to a modest 21,000,000 miles. Decline is as gradual and as marked as growth, the colours returning in inverse order as the star approaches final extinction. With decrease of volume and increase of density, the stars exhibit more rapid motions in space. The reason and the bearing of this fact are not yet fathomed, but certain it is that stars of small mass move more rapidly on the average than those of large mass, and further those with large velocities are moving toward the centre of the Galactic system.

The rapid accumulation of stellar parallax determinations and the measurement of the diameter of the stars, the director regards as two outstanding events that makes the past year memorable. A third is the intimate connection and close co-operation of the Observatory with a great physical and chemical laboratory, manned, equipped and endowed for the investigation of the constitution of matter, a problem which Dr. Hale believes can be more effectively approached by the astrophysicist, than by either the chemist or the physicist. Be that as it may, we are quite sure the acceptance of the post of the director of the Norman Bridge Physical Laboratory, by Professor Millikan, of Chicago, will prove epoch-making, and that the usefulness of the Laboratory and of the Observatory will be mutually extended. Economy of apparatus will not be the least of the advantages. The want of high voltage had been experienced at the Observatory, but the possession of a 1,000-kw. transformer, giving 1,000,000 volts, will be part of the equipment of the Laboratory and available for astronomical and physical investigations.

The necessity for heavy voltage is shown when examining the emission and absorption spectra of metals, in which temperatures higher than 3,200 deg. C. are produced and used with effect. Also in experiments designed to detect the Stark effect in the Sun-spot spectrum. In this latter inquiry has been used a powerful solenoid magnet, constructed for use with currents up to 4,000 amperes giving a uniform field of 33,000 gausses, into which were inserted specially designed quartz vacuum tubes. A sufficiently high voltage current was available for preliminary trials, but no definite conclusion could be drawn. Higher dispersion and a steadier electric field are essential to success, and in accordance with the tradition of the Observatory, steps are being taken to secure improved apparatus. Similarly with the attempt to detect the shift of the Solar lines, predicted by Einstein as a consequence of this theory. An authoritative pronouncement is awaiting the results of preliminary experiments that will ensure the removal of all possible sources of error. The fulfilment of this prediction of the shift of the lines in the solar spectrum has come to be regarded as a critical test for the theory, and many spectrocopists have been eager to demonstrate a minute displacement in accord with the demands of the theory. Their premature decisions, however, are based on the application to the original observations of various numerical corrections, whose amount is unsupported by legitimate and thorough inquiry. Of the contradictory evidence that has been deduced, the director observes, "that owing to the different and even inconsistent corrections applied by the various observers, their announced agreement of observation with the deductions from the Einstein theory fails to carry conviction. No final conclusion seems to be warranted that is not based on an exhaustive study of pressure shifts, variations with temperature, pole effect, motion in the solar atmosphere and other phenomena." The inquiry at Mount Wilson which is being actively prosecuted will be long, but it will be conducted with patience and method, and the verdict will be accepted.

An instance of the accuracy with which spectroscopic measures can be made is furnished by the proof this method has afforded that both oxygen and aqueous vapour are absent from the atmosphere of Venus. Using the high dispersion of three Angstroms per millimetre, the lines originating in the atmosphere of Venus were distinctly separated from the telluric lines of the same origin, when the relative velocity of Venus and the Earth was large, but there was no trace of the water vapour lines at λ 5,900 or of the oxygen lines in the a and B bands at λ 6,300 and λ 6,390, though the lines produced by the Earth's atmosphere were clearly visible. Imagination had readily jumped at the facile conclusion that, owing to a certain similarity in the size and position of the planet, the meteorological conditions obtaining would resemble those on the Earth. Recalling, however, the slight indications of oxygen in sunspots and the abundance of unoxidised material on the Earth, it is more plausible to suggest, that oxygen is a rather rare element in the solar system, and it is pointed out that a planet formed from the outer layers of the Sun, a not improbable origin, would contain little oxygen. It is suggested that in the case of the Earth's atmosphere, the oxygen may be an organic product given off by vegetation during geologic time and balanced by an accumulation of carbonaceous organic residues in the sedimentary rocks.

The 100-in. telescope has been much employed in investigating the galactic nebulæ and with the globular nebulæ which are very numerous. These latter objects resemble spiral nebulæ in spectrum and radial velocity, but even the largest afford no evidence of spiral structure. On the other hand, many of the smaller are expected to prove spirals when greater magnification can be employed, and some, spindles when longer exposures bring out the ansæ. Just as the division in the Aquila region of the Milky Way is probably due to great clouds of dark nebulosity, so it is suggested that many nebulæ obscure in part the stars beyond, or within, them. The forms of the nebulæ indicate the action of repulsive forces emanating from associated stars, at least, the forms can be more readily interpreted by a process of repulsion than one of attraction. Hind's variable nebula in Taurus and some others have been under examination, but the most interesting case is that of a nebula in Corona Australis, which showed marked changes while the involved star, R. Coronæ, was brightening rapidly. In two nights, a bright envelope which expanded from 4 seconds to 12 seconds in diameter, developed about the star. On the assumption that this phenomenon was due to a wave of illumination travelling outwards with the velocity of light, the distance of the object would be 290 light years, a distance that agrees with that deduced by other methods. On the scale on which the stellar universe is built, such a nebula is quite a near neighbour of our Sun. For the blue stars of the fourteenth magnitude a distance is assigned varying from 20,000 to 50,000 light years, but these are minimum values and are dwarfed by a remote cluster, whose light requires 220,000 years to cross the space that intervenes between it and our Sun.

The measures of internal motions in spiral nebulæ have been continued, and confirm previous results. The observed displacements in all cases correspond better with a motion along the arms of the spirals than with a rotation. Accepting the evidence, which gains in strength with the lapse of time, the result affords substantial support for the theory of Dr. Jeans, since the observed phenomena indicate that matter is thrown off from two points of a nebula after it has been reduced by rotation to a lenticular form.

Mention of many investigations of a technical character must be omitted, and others in progress will best be referred to later. Among these latter is included one which has for its object the repetition of the Michelson-Morley experiment, to decide whether increase of altitude above sea-level has any appreciable effect on the perception of possible relative motion of the Earth and the ether. Another refers to the determination of the velocity of light by observations between Mount Wilson and a station at Whittier. In preliminary trials, the beam was observed, but it was clear that the illumination was insufficient and that the adjustment of the distant mirror was inadequate. Professor Michelson has suggested some improvements in the optical apparatus, and another trial will be made under more favourable atmospheric conditions between Mount Wilson and a station 22 miles distant.

The instruments under construction contain few novelties. Among the more interesting is the machine for ruling gratings, mentioned in previous reports. The gratings ruled last year showed false spectra due to the spacing mechanism. The cause of the error being discovered, the accidental errors appear to be completely removed in the newly-designed arrangements. There remains now but a small and periodic error due to slight residual eccentricities in the spacing wheel and the screw pivots. This error amounting to $\frac{1}{250000}$ in., can be removed either by a correcting mechanism or by direct working on the eccentricities. The latter course will be adopted.

NOTES.

EVENING CLASSES.

FROM the presidential address of Mr. J. Paley Yorke to the Association of Teachers on Technical Institutions it appears that local authorities are often prone to gauge the importance of a class by the number of students attending it. It would, perhaps, be going too far to claim that a class is more "socially advantageous" the fewer its numbers, but such a contention would be nearer the truth than the more popular view. Unfortunately, but a relatively small proportion of our population has either a liking for science or the intellectual capacity to appreciate its methods. Evening classes commonly commence each new academical year with full numbers, but the majority lacking the ability to master even elementary principles soon faint by the wayside, and those that finally take up the more advanced work constitute generally but a very small fraction of the original horde. This small residuum is, however, that which will best repay teaching, and if economies have to be effected these had better be realised by reducing the size of the elementary classes rather than by abandoning the more advanced training of the few who are capable of profiting by it. No doubt the whole of our population would gain by some training in the methods of science, although past experience shows that even scientific men of some standing often fail to think scientifically on all matters not directly connected with their researches. Mr. Yorke notes that in most cases a technical teacher is required to give his whole time to the duties of his post. Such a restriction should, however, be the exception rather than the rule, at any rate in the case of the higher and more responsible positions. It is most important that direct touch with industry should be maintained, both in the interests of the pupils and in that of our manufactures. Unfortunately, many of these higher posts are at present filled by men with

but limited practical experience, and the regulation in question prevents them acquiring more. They are thus, to the detriment of their efficiency as teachers, often driven to devote most of their energies to studies of which the interest is mainly academic.

UNDERGROUND IMPROVEMENTS.

In a memorandum issued last week to the London Members of Parliament Lord Ashfield describes the important programme of extensions and improvements of the Underground Railways, which are to be carried out under the Trade Facilities Act. The works include the Edgware extension railway already authorised. This is a line 4¼ miles long, from Golder's Green to Hendon and Edgware. It will serve an area as yet but partially developed, and there will be five new stations. Another important work to be proceeded with is the construction of the authorised connecting lines between Camden Town and Euston, which will make it possible to work trains from Hampstead line to Clapham Common *via* the Bank, once the enlargement of the tunnels of the South London Railway is completed. This latter work is also comprised in the programme. The minor works to be undertaken include extensions to Lots-road Generating station and the provision of escalators at a number of underground stations now served by lifts. The above undertakings have been rendered practicable by the fall in the cost of labour and the cost of money. As regards the latter, the Treasury, under the Trade Facilities Act, will guarantee the principal and interest on the capital involved to a total not exceeding 6,000,000*l*. The stock will be issued at rates not exceeding 5 per cent. The interest charges will be secured not only on the net earnings of the respective companies, but also by the common fund of the whole five companies of the group. Contracts have already been placed for a large part of the work, and the whole of the plant required with the exception of certain parts of the escalators will be manufactured in this country. Employment will thus be found for about 20,000 men.

DECLARATIONS OF LIABILITY FOR WORKMEN'S COMPENSATION.

The Court of Appeal gave judgment on June 1 in five cases, Foster and others *v.* Wharncliffe Woodmore Colliery Company, Limited, on the right of an injured workman to what is called a declaration of liability. The workmen's applications for a declaration were based on the leading case of King *v.* The Port of London Authority in the House of Lords in 1919, in which it was decided that where an applicant had met with personal injury which had not produced incapacity at the date of the arbitration but was of such a nature that it was probable that partial or total incapacity would ensue as a result, the arbitrator might make a declaration of these facts and adjourn the arbitration so that in the event of the workman becoming incapacitated at a later stage he could then make an application to the arbitrator for compensation. In the five cases in question the applicants had been paid compensation for a time, and had subsequently returned to work at wages which were at least as high as they received before the accident. The accidents happened some years ago—two of them as far back as 1912—but for some reason the men only recently made an application to an arbitrator (the County Court Judge at Barnsley) for a declaration of liability. The arbitrator made a declaration of liability on the ground that the men had become "odd lots" in the labour market, but the Master of the Rolls (Lord Justice Scr itton and Lord Justice Younger concurring) held that that was not the proper ground for such a declaration. He mentioned that Lord Moulton, who invented the expression, did not say that the man was an "odd lot," he referred to the workman's labour becoming an "odd lot" in the market; but in the present case there was no evidence of such a state of affairs as regards the applicants' labour. The proper grounds for a declaration of liability were those laid down by the Lord Chancellor in King's case, viz.: (1) That the applicant had received injury by accident arising out of, and in the course of, his employment, (2) that there was no incapacity at the moment, but (3) that it was reasonably probable that incapacity would arise at a later date. In two of the five cases the court held that no such probability had been proved and that the men were not entitled to a declaration; but in the other three there was such a probability, and the declarations were allowed to stand.

THE INSTITUTION OF ELECTRICAL ENGINEERS.

(*Concluded from page* 692.)

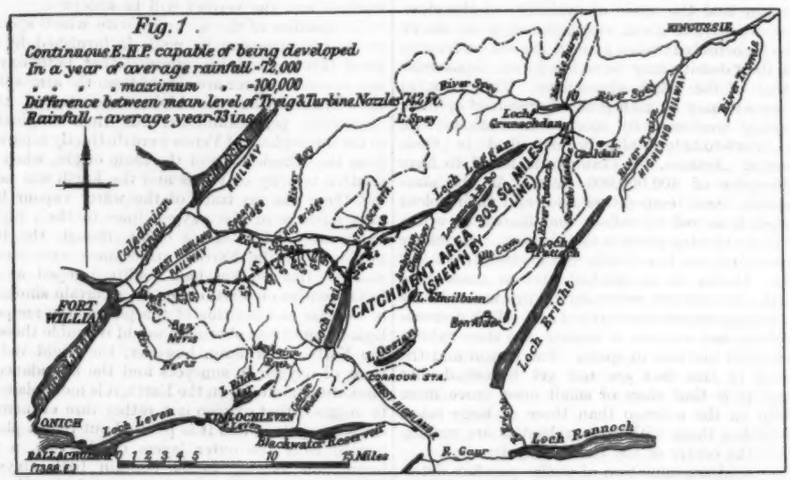
CONTINUING our account of the summer meeting of the Institution of Electrical Engineers, at the Scottish Centre, we may now turn to the details of the proceedings of Wednesday, the 31st ult., which the exigencies of distance and time did not allow us to deal with fully last week. The proceedings on that day opened with a paper by Professor Magnus Maclean, at the University of Glasgow. The Institution was welcomed to the University by the principal, Sir Donald MacAlister, who, in the course of his speech, referred to the fact that the meeting was being held in the History Class Room, in which Lord Kelvin had lectured for so many years and had "laid the foundations of electrical engineering." This expression was perhaps something of an hyperbole, but in view of the circumstances Sir Donald may be forgiven.

Professor Maclean's paper was entitled "The Hydro-Electric Resources of the Scottish Highlands." In it he gave a sketch of the existing installations at Foyers and Kinlochleven of the British Aluminium Company, and described in outline the projected schemes at Lochaber and the Grampians. As is generally known, the Lochaber scheme is also associated with the name of the British Aluminium Company. The catchment area of this scheme amounts to 303 sq. miles and a water supply equivalent to 100,000 h.p. is anticipated in all but the drier years. As an inspection of some of the features of the county coming within the Lochaber scheme formed part of the programme for the following day, we will deal more fully with the details of the project when dealing with that part of the visit.

In the Grampian water-power scheme the catchment area is 417 sq. miles, and Professor Maclean stated that the four proposed power houses would have a total continuous horse-power of 56,000. The four stations would be Tummel, of 17,400 h.p.; Garry River, 7,500 h.p.; Bruar River, 4,200 h.p.; and Loch Rannock, 26,900 h.p. The first part of the scheme beginning with the Tummel station would cost 2,603,000*l*., and the whole scheme 4,500,000. Professor Maclean did not analyse these figures, but it will be seen that they work out at an overall cost of about 40*l*. a kilowatt. It may be of interest briefly to compare this figure with steam practice. The cost of Lots-road station of the Underground Railway worked out, we believe, at 21*l*. a kilowatt. From the point of view of modern central station practice Lots-road is, of course, an early station and includes double deck boiler houses, brick chimneys and other expensive items, and comparison may perhaps more profitably be made with a modern station such as Dalmarnock, with which we dealt last week.

The total cost of this station before the war was estimated at 10*l*. a kilowatt of plant installed, but owing to the construction falling entirely in the war and post war periods the cost has actually come out at 20*l*. per kilowatt. Incidentally it may be noted that both in the description of Dalmarnock supplied in connection with the summer meeting and in the paper which Mr. Mitchell read before the Institution of Engineers and Shipbuilders in Scotland, in March of last year, it was stated that the cost of the second half of the station would be "much more" than 20*l*. a kilowatt. We do not know on what this estimate is based, but it is interesting and pertinent to note that in a paper read before the Institute of Transport on the 8th of last month, Mr. Roger T. Smith stated that the effect of the adoption of higher running speeds and other improvements was that "to-day the cost per kilowatt of plant capacity is the same, and in favourable cases even lower than it was before the war." Mr. Smith's paper included a table compiled by Mr. J. S.

Fig. 1.



which it contained, but should make some reference to the general considerations bearing on the utilisation of water power which formed one of its important features. It was quite evident that Professor Maclean had much enthusiasm for his subject and for the way in which its application might improve the economic condition of the workpeople of the Highlands. For several generations the Highlands had been pouring their best manhood and womanhood into the cities and towns, the glens had been becoming more and more desolate, and much of the land had been going out of cultivation. The extent of the Highlands was 40 per cent. of that of Scotland, but only 7 per cent. of the population was contained in their area. Hydro-electric power, by introducing local industries and giving the equivalent of a local coal supply, should do much to arrest these tendencies. There is certainly much truth in this case which Professor Maclean presented, but in following it up by calling coal mining "barbarous and unnatural" and suggesting that the industry and economic standing of these islands could ultimately rest on oil and water-power, we fear he allowed his enthusiasm to run away with his judgment.

After the reading of the paper a vote of thanks was moved by Mr. Roger T. Smith and seconded by Mr. C. H. Wordingham. Professor Andrew Gray also spoke and put in a plea for some attention to elegance in the villages which would presumably be built in connection with the development of water powers. In the afternoon following this meeting a visit was made to Messrs. Babcock and Wilcox's boiler works at Renfrew. The trip from Glasgow to Renfrew was made by steamer at Messrs. Babcock's invitation, and after the inspection the evening was spent in a trip in the Clyde estuary. The party was fortunate in having very favourable weather and the day proved most enjoyable. There was no formal ceremony in connection with this visit, but on the return journey to Gourock the president expressed the thanks of the Institution and Sir James Kemnal replied. We cannot here attempt any description of the Babcock and Wilcox works, but it is permissible briefly to say that the feature of the works which most struck us was the very large machine tool equipment for a boiler works and the number of machines obviously specially built for the work on which they were engaged.

The programme of Thursday, the 1st inst., covered the train journey from Glasgow to Fort William, and the inspection *en route* of the source of supply of the Lochaber water-power scheme. The journey from Glasgow was made by the West Highland Railway through Dumbarton and Helensburgh, and up the side of the Gare Loch and Loch Long and across Rannock Moor. Again very favourable weather was experienced, and as the line passes through some of the most beautiful and rugged scenery in Scotland, a very enjoyable day was spent. The latter part of the run is indicated in Fig. 1, on page 724, which is a map of the country covered by the Lochaber scheme. As we have already mentioned, this area covers 303 square miles. The rainfall in the area covered is 73 inches per year, so that 876,000,000 gallons of water a day are available, equivalent to some 100,000 h.p. The British Aluminium Company, which, as we have said, are associated with the scheme, expect to utilise most of the power themselves and to employ some 3,000 additional workpeople. It need not be said that an industry of such magnitude would be of great importance to the Scottish Highlands.

FIG. 2. RIVER SPEY AND SITE OF RESERVOIR ABOVE PROPOSED DAM.

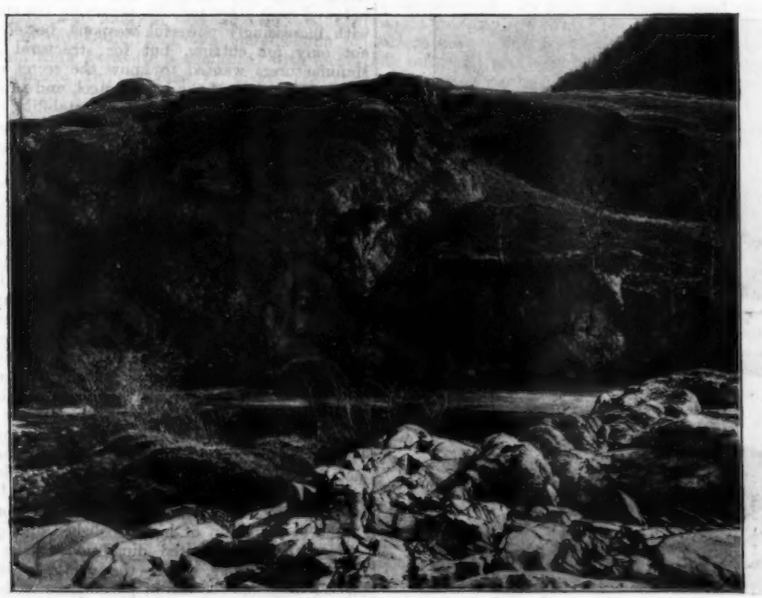


FIG. 3. SITE OF SPEY DAM, LOOKING SOUTH.

The general lines of the scheme may be followed from Fig. 1, on page 724, and the following notes:—At the eastern end of the area a dam with a weir is to be formed on the River Spey at the point at which the Markie Brook joins it. This dam, shown at 10 in Fig. 1, will raise the level of the Spey by about 30 ft. at flood time and will form a reservoir connecting up with Loch Crunachdan. Normal water supply is to be allowed to flow eastward down the Spey, but the effect of the weir will be to divert all flood water into Loch Laggan. There was some opposition to the scheme in connection with interference with the Spey on the score that it would act unfavourably on salmon breeding in the river. It is anticipated, however, that the more regular flow which the weir will ensure will be favourable rather than otherwise. An excellent idea of the River Spey as it at present exists is given in Fig. 2 annexed, from which it will be clear that the site is a very suitable one for impounding surplus water. The site of the dam is shown in Fig. 3. As will be seen from the map, a conduit is to be constructed to carry the surplus water from the weir to Loch Laggan, while a branch conduit with an intake will collect flood water from the River Mashie. There is a fall of about 20 ft. from the Spey dam to the point on the River Pattach at which the conduit delivers.

Loch Laggan is at present about seven miles long and a dam, shown at 1 in the map, is to be built about three miles downstream on the River Spean which drains the loch. This will result in the flooding of this three miles of river and the formation of a reservoir joining up with Loch Laggan. The surface of this loch will not be raised above its normal winter level, but the whole of the extra storage water impounded by the dam will, of course, become available. A view of the River Spean taken from the railway bridge is given in Fig. 4, on page 726. The part of the river actually shown in this figure is somewhat below the site of the proposed dam, as will be clear from Fig. 1. From the Laggan Dam, a tunnel about four miles long is to be driven to connect up with Loch Treig. This tunnel, which is indicated at 4 on the map, will have a total fall of 41 ft. in its length. The water from various small streams will be collected on the way by means of vertical shafts.

Loch Treig, to which this tunnel will deliver, will act as the main collecting reservoir of the whole scheme, and will connect up by a pressure tunnel directly with the turbines at Fort William. The present level of the loch is 783 ft. above Ordnance Datum and is 37 ft. below the level of Loch Laggan. It is a deep loch some five miles long. It is proposed to dam the north end and raise its level some 36 ft., to 819 ft. above Ordnance Datum and 1 ft. below the maximum level of Loch Laggan. The site of the proposed dam is indicated at 2 on the map. The raising of the level of Loch Treig will involve reconstruction of some part of the West Highland Railway which, as can be seen from Fig. 1, follows its eastern bank. The loch, with the railway, are shown in Fig. 5, which is a view taken from near the north end of the loch and looking southward. The loch is a very beautiful one, as will be clear from the figure, and the slow railway run which was made down the side of the loch last week proved one of the most attractive parts of the journey.

As we have already indicated, Loch Treig is to

connect up with the power house at Fort William by means of a pressure tunnel. This tunnel, indicated at 5 in Fig. 1, will have a length of 15 miles and a diameter of about 16 ft. At its western end a surge chamber will be formed, and the tunnel will connect to a pipe line leading to the power house. There will be nine pipes each 4 ft. 6 in. diam. In the length of the tunnel various small streams will be tapped and connected to the main supply by vertical shafts. These streams are indicated at *5a*, *5b*, &c., in Fig. 1. This 15-mile long Loch Treig and Fort William tunnel will form one of the chief engineering features of the Lochaber scheme. The tunnel will tap Loch Treig 139 ft. below the raised top level of the loch. The invert level at the inlet end will be 680 ft. above Ordnance Datum and at the outlet end 640 ft. above Datum, so that there will be a fall of 40 ft. in the 15 miles length. The top level of Loch Treig, as already stated, is 819 ft. above Ordnance Datum and the lowest level to which it can be run is 695 ft. above Datum, so that there is a possible difference of level of 124 ft. on which the tunnel can draw. It is intended to fix the turbines at Fort William at about 15 ft. above Ordnance Datum, and as the invert level at the outlet end of the tunnel is 640 ft. above Datum, there will be a fall of 625 ft. in the pipe line.

During the visit of last week an excellent idea of the country concerned in this important hydro-electric scheme was obtained. Loch Treig was seen during the train journey, and a stop was made at Tulloch Station to inspect the country in the neighbourhood of the Laggan Dam. The view given in Fig. 4 was taken from the neighbourhood of this station. The evening of Thursday of last week was spent at Fort William, and on Friday the journey to Oban was made by steamer. On the way a visit was paid to Kinlochleven by invitation of the British Aluminium Company which provided lunch for the party. The Kinlochleven works have been described many times in the past, and there is no need for us to deal with them in any detail now. The station has a load of 20,000 kw. and generates at 275 volts D.C., the aluminium furnaces being connected in banks in series. The operation is a continuous one and provides an ideal load for a hydro-electric plant. It was matter for considerable satisfaction in these days of slack trade to find the plant working to its full capacity.

Kinlochleven lies at the head of Loch Leven and quite out of the way of ordinary traffic. Main communication with it is by steamer, but during the war a road along the cliff side from Ballachulish, where there is a railway connection, was begun by German prisoners of war. This road has since been completed and has put Kinlochleven more easily in touch with the outer world. After the lunch at the aluminium works the thanks of the Institution were conveyed to the British Aluminium Company by the President and the journey was resumed to Oban, where the visit terminated. The arrangements ran without hitch throughout and reflect great credit on the committee of the Scottish Centre, and on Mr. E. T. Goslin, its chairman, as well as on Mr. P. F. Rowell, the secretary of the Institution.

FIG. 4. RIVER SPEAN FROM RAILWAY BRIDGE.

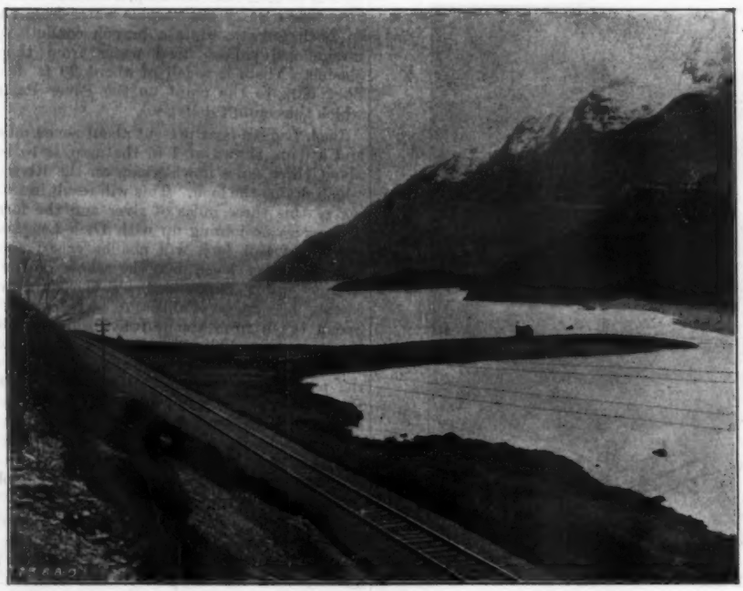


FIG. 5. LOCH TREIG, LOOKING SOUTH.

LITERATURE.

An Introduction to the Study of Metallography and Macrography. By LEON GUILLET, Docteur ès Sciences, and ALBERT PARTEOIN, Ingénieur des Arts et Manufactures. Translated by LEONARD TAVERNER, A.R.S.M., D.I.C. With an introduction by Professor H. C. H. CARPENTER, F.R.S. London: G. Bell and Sons, Limited. 1922. Price 30*s.* net.]

METALLOGRAPHY had its origin as a practical science and aid to industrial processes in the work of the late M. F. Osmond, who laid the foundations truly and well. We welcome cordially the appearance of this volume, in which the usefulness and scope of Osmond's epoch-making work is extended and enriched by the assiduous labour of his eminent countrymen. More than a century ago, Widmanstætten applied methods of polishing and etching to the surfaces of metals and alloys, which could give useful information if correctly interpreted, but no progress was made till Osmond showed what could be learnt by abrading the surface of steel with a sewing needle, and examining the scratch microscopically. An immense impetus was given to the employment of his processes by the successive improvements introduced into steel manufacture from the end of the last century onward. Tungsten-steel, tungsten-chrome steel, vanadium steel, followed each other rapidly, supplying the engineer with increasingly powerful weapons, better fitted not only for cutting, but for structural steels. Manufacturers wanted to know the secret of the cutting efficiency of the harder steel, and to understand the reason for the thermal stability of the products that worked so marvellously. Chemists talked rather vaguely about allotropic changes on the one hand, and the possibility of vanadium wresting the carbon from the carbide of iron on the other, hypotheses which are perhaps still maintained by ardent supporters on insufficient evidence. But the thermo-mechanical behaviour of high-speed steels, as of many other alloys, needed a new analysis to unravel all the changes in the combinations, and the methods of Osmond supplied the mechanism which has been developed and extended by a succession of eager investigators.

The success that has attended these inquiries is exhibited in this volume, in which two original investigators, holding important positions in the French metallurgical industry, demonstrate what the inquiry has achieved and of what it is capable. The authors divide the subject into two branches, metallography and macrography, but the difference between them is one of degree rather than fundamental. In the former, the investigation is confined to the examination of highly-polished and etched surfaces of very limited dimensions under high magnifying powers, while the complete inquiry further demands the use of pyrometers of delicate construction, recording chronographs, indeed all the appliances of a specially equipped laboratory. But the conclusions drawn, whether microscopical, or chemical, or mechanical, refer strictly only to the small samples under investigation, and the assumption that the conclusions are applicable throughout the whole mass of material is only warranted, when the casting or forging is of uniform structural and chemical composition. A systematic inspection of the interior is needed, and this is best effected by cutting sections in various directions through the metal, and examining the surfaces by the naked eye or low magnifying power after they have been polished and suitably etched. This preliminary survey is the work of macrography, it is eminently practical, and is limited to the study of the "coarse" structure of the metal or alloy. The information afforded is of real assistance to those

engaged either in manufacturing or using metals, while the neglect of such a precaution may cause quite erroneous conclusions to be drawn from the more elaborate method.

The authors have kept in view as their main object the benefit of industry, but as the science is based on physico-chemical laws, they have demonstrated its theoretical foundation. In the earlier chapters therefore are described not only the method of investigation and the apparatus necessary for thermal analysis, but the theory of metallography is sketched generally. The "phase rule" of Willard Gibbs, the "equilibrium diagram," and eutectic temperatures are not subjects that can easily be made interesting, but by the manner of treatment, the authors discuss the relations between the equilibrium diagram of alloys and the properties of these in a way that will prove attractive to many. This interest is sustained and increased by the eminently practical view that is maintained throughout, the authors contriving to satisfy the needs of those who require some insight into the theory on which the science is built, while providing the precise information demanded by those who are engaged on the commerical side of the industry. This regard to works practice is particularly shown in the chapters describing the constituents and structure of carbon and alloy steels. The gradual changes from austenite through martensite to pearlite, in which chain the debateable osmondite appears, are very clearly traced, great assistance being given by the excellent micro-photographs illustrating the changes produced by quenchings progressively less severe, or by annealing quenched steels at an increasing temperature.

As evidence of the practical value of the method to the manufacture or user of steel, it is pointed out that the simpler examination of the microstructure is generally sufficient to identify an element present in special steels, or to limit the number of possible elements present. For instance, the recognition of graphite will indicate silica: carbides, the presence of chromium, tungsten, molybdenum or vanadium, while austenite is connected with nickel or manganese. In the case of nickel steel, a diagram is given to illustrate the variation in the properties with increasing nickel content, as derived by mechanical tests. More of such diagrams would have been instructive and would have brought out more clearly the practical value of mechanical tests. The comparison of the methods and apparatus used abroad with those approved in this country, so far as it is possible, is however not uninstructive. The instrumental equipment as employed in tensile, compression, and other tests, is naturally of French construction, and some of the apparatus exhibits considerable ingenuity, but no evident superiority over other appliances is displayed. The hardness test may be taken as a single example. The indentation method of the Brinell arrangement is given and the form of scleroscope by Shore is figured and described, in which the amount of rebound of a weight from a known height is made the measure of hardness of the object struck, but this method is of questionable validity. The nice adjustments of the forms due to Steeg and Reuter, or to Fuess, are not mentioned. Something more might have been said of the sources of error or of possible misinterpretation of the results. In this very practical section the tests of resistance to wear seem to claim attention.

The impurities ordinarily encountered in industrial metals are dealt with very thoroughly, but less work has been done in connection with the microscopic structure and the mechanical properties of these alloys than in the case of iron and steel. The investigations, however, are not less interesting or the conclusions less definite. In addition to ordinary brass, a section is devoted to the description and figuring of special brasses, that is a brass in which a third element is added to a copper-zinc alloy.

Similarly, special bronzes in which phosphorus or aluminium are mixed with copper and tin are passed in review. An example of a ternary system in which lead, tin, and bismuth are combined is also discussed in connection with the structure of compounds suitable for use as bearing metals, the peculiar properties which the contact surfaces should possess being considered fully.

Reference to the methods and results of macrography must be brief. As already intimated the object of the inquiry is to determine the general character of the structure of the material, and to ascertain whether the ingot or specimen is of uniform chemical composition. The polishing and etching of the sample to be examined require care, but since only low magnifying powers are used, great delicacy of manipulation is not needed. If unequal etching be perceptible, it may be regarded as evidence of heterogeneity, either crystalline, mechanical or chemical. With worked steels, rolled or forged, the grains are generally too small to be seen with the low powers recommended, but with ferrous alloys this condition may be perceived in cast metal or burnt steels. If mechanical heterogeneity is present, the effects of irregular and local hardening will be revealed by such parts of the alloy being more readily attacked. Want of chemical homogeneity will be betrayed by the rapidity of the attack on the impure portions, such as sulphides, oxides, silicates, &c., either because the reagent attacks these more readily then the remainder, or because they become the centres of electrolytic action, tending to the corrosion of the surrounding metal. This heterogeneity, when detected, may arise from cementation, or to the method of manufacture, as in welding, but the phenomena of liquation and segregation accompanying solidification are always present, more or less, giving rise to effects that are modified by the temperature and rate of casting, the nature of the metal, the viscosity of the liquid, the form of the ingot mould, the amount of agitation due to the escape of gas and other causes, on which macrography can throw little or no light, but which do not always receive the attention they deserve. The point made is that by examining the surfaces of the sections it is possible to obtain a series of isochemical curves outlining the impure portions of the material. In place of etching, good results can be obtained when sulphur or phosphorus segregations are present, by bringing bromide paper or silk saturated with acid bichloride of mercury into contact with the prepared surface. Sulphides and phosphates decompose with evolution of H_2S and PH_3, which discolour the paper or silk locally, and thus furnish an exact image of the localities rich in phosphorus or sulphur.

Though metallography has been longer and more ardently studied than the rougher method, it is evident that a careful study of macrostructure of a metal or an alloy should precede the rigorous investigation of its microstructure. In the testing of steels this practice is usually followed, but less exact knowledge is available of the structure and behaviour of alloys of copper, tin, aluminium, &c. The authors descriptions and illustrations therefore of castings of brass and aluminium bronze are the more welcome, as they are the more instructive, since they have the advantage of presenting larger crystals for examination and it is understood, these have not been previously published. They show well the arrangement and outline of the grains as influenced by the nature of the casting. In a series of cupro-nickel-aluminium alloys, the dendritic structure and outlines are clearly to be perceived in the diagrams photographed with quite small magnifying power. Indeed, one may say in conclusion that throughout the book, the lavishness and beauty of these reproductions constitute a great feature. They convey an immense amount of information and repay the closest study.

Petroleum: A Treatise on the Geographical and Geological occurrence of Petroleum and Natural Gas; the Physical and Chemical Properties, Production and Refining of Petroleum and Ozokerite; the Characters and Uses, Testing, Transport and Storage of Petroleum Products; and the Legislative Enactments relating thereto; together with a description of the Shale-Oil and allied industries. By SIR BOVERTON REDWOOD, Bart., D.Sc. Fourth Edition. In three volumes. London: Charles Griffin and Co., Limited. [Price 3*l.* 5*s.* net.]

THE history of the evolution of a great industry, told by a master who watched over and so often guided its development, must possess a deep interest. In this case the interest is increased by the knowledge that the author's researches are ended and that his wide information and matured experience, so willingly placed at the service of all, are no longer able to stimulate or to influence. His treatise on petroleum, now in the fourth edition, has become an acknowledged classic which many experts in all parts of the world have consulted with confidence and satisfaction. These now repay in some measure their teacher by supplementing and revising the sections that were left incomplete by the sudden death of Sir Boverton Redwood. But for its length, we would willingly have reproduced the list; it must, however, suffice to say that those most prominent in the petroleum world have been proud and willing to offer their contributions towards completing the work on which Sir Boverton laboured so long and so successfully. One exception must be made to this unwilling suppression of the names of the eminent coadjutors, that of Sir Frederic W. Black, who has supplied a biography and an appreciative foreword, in which he has endeavoured to voice the sense of admiration and esteem all must entertain for a revered and enthusiastic leader.

Just as it is impossible to do justice to the work of the many co-operators who have revised or amended the previous edition, so it is impossible to indicate adequately the scope and variety of the contents of the enlarged treatise. The contents of the three volumes are divided into eleven sections, or one might say, separate monographs, so thorough and complete are they in arrangement and detail, besides appendices, giving full statistical data relating to the production of crude oil, natural gas, ozokerite and shale oil in the producing countries of the world; precise information of the import duties levied on petroleum and its products in foreign countries and a bibliography extending over 160 pages, that would have been even more comprehensive but for the present high cost of type-setting. Among these valuable compilations, necessary for furnishing a complete picture of the activities of the petroleum industry should be mentioned the elaborate and accurate maps that have been specially drawn for this work.

Consider what is involved in tracing the development of the petroleum industry, even if we limit the history to the time when Drake successfully tapped the oil sands at Titusville, or the first flowing well struck in 1861, a date well within the memory of many now living. In that one lifetime the world has seen a display of energy and ingenuity that it is difficult to appreciate, even under the competent guidance of one, who has visited every great oil field in the globe and has described the enterprise exhibited in exploiting, and the success that has attended the efforts to tap new sources of energy and power. From the United States alone the total production of petroleum utilised must now far exceed 5,000 million barrels of 42 gallons each, figures, however, that we are as incapable of realising, as we are those with which astronomers delight to dazzle our imagination.

There is, however, another and an earlier question to which an answer is expected. How did these immense stores of petroleum, natural gas, and other associated products collect within comparatively small areas? Were they deposited in the positions in which they are found, or have they filtered through the superficial strata undergoing chemical reaction and changing their composition as these strata have modified their form and shifted their position throughout the geologic ages? Have they an organic or inorganic origin? Such questions have formed the subject of interminable controversy and remain unsettled; the chemist, the geologist and the petroleum expert all finding evidence wherewith to confute his opponent. This evidence, differing in relevancy, is drawn from all parts of the earth, the differences of geological structure introducing many doubtful factors, and from petrols whose chemical and physical properties differ materially. Nevertheless, the salient points urged with so much force by specialists, are all weighed with care, presented with impartiality, and allowed their due weight in the solution of the problem. Still a confident conclusion eludes us.

Having located a source of supply, the mechanical task of drilling has to be undertaken, and remembering that each producing area has its own methods, Americans approving the cable system, the Canadians the pole, giving greater rigidity, and the Russian a free fall with square iron rods, it will be

gathered that the mass of descriptive material to be examined and commented upon is well-nigh bewildering. The tools for drilling, and devices for preventing waste, vary with the district and local conditions. But these many types receive critical examination and illustration. Further, the winning of the crude petroleum marks only the beginning of many technical processes. Without the possibilities of fractional distillation, giving rise in succession to petroleum spirit, burning oils, gas oils, lubricants, and where possible, to paraffin, the industry would not have attained the dimensions it has acquired, and its extension is being promoted by the introduction of new, and the improvement of old, methods. Hence sections must be devoted to the work of "cracking" and refining, to the task of purification and desulphurisation, and modes of chemical treatment necessary to bring the various products into a marketable condition.

But the markets are far from the oil fields, and the problem of transport, storage and distribution demands careful consideration. This section is particularly interesting as it exhibits the influence exerted by petroleum in other industries, and the stimulus it has given to the world's commerce. The construction of pipe lines and pumping apparatus has attained enormous dimensions, and the provision of tank steamers and railway tank cars is on a similar Gargantuan scale. To allow the penetration of petroleum products into all the nooks and corners of the globe has required many aids to distribution, and the manufacture of these has practically created new industries. These products are not confined to illumination or to fuel, but find wide application in many arts and sciences: in pharmacy, lubrication, ore concentration, electric insulation, dyeing, and a host of other outlets which are adequately treated in this encyclopœdic work. Naturally so large and varied use of the products demands that a trustworthy system of testing, based on recognised standards of quality, should be established in order to satisfy the refiner that his processes are being accurately and economically conducted, and also to protect the buyer. This is a large subject on which it is known Sir B. Redwood worked assiduously and successfully; and his presentation of the schemes of Sir F. Abel, Dr. Kellner and other associates is especially instructive. The authors' own tests for the detection of petroleum vapour, for the burning quality of oils, together with his viscometer, form notable contributions to the many devices with which ingenuity has enriched the technical developments. These, with much other matter, historical, technical and statistical, invite extract and comment, but short quotations would fail to do justice to the thoroughness and exactness that pervade the authoritative information bearing on every branch of the petroleum industry.

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Transactions of the Institution of Gas Engineers, 1920–21. Edited by WALTER T. DUNN, F.C.I.S. London: Offices of the Institution.

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Switching and Switch Gear. An Introductory Treatment of the Principles of Switching, &c. By HENRY E. POOLE, B.Sc., A.C.G., A.M.I.E.E. London: Sir Isaac Pitman and Sons, Limited. [Price 2*s.* 6*d.* net.]

The Testing of Transformers and Alternating Current Machines. By CHARLES F. SMITH, D.Sc., M.I.E.E., Assoc.M.Inst.C.E., Wh.Sc. London: Sir Isaac Pitman and Sons, Limited. [Price 2*s.* 6*d.* net.]

A JOURNAL OF SCIENTIFIC INSTRUMENTS.—The Institute of Physics, impressed with the need of a journal dealing with methods of measurement and the construction and use of instruments, has under consideration the publication of a journal bearing the above title. In Germany there are some four or five journals which cover this field and one of these, which devotes itself entirely to the subject of scientific instruments, has been of great influence in imparting a sense of the importance of scientific methods in the study of technical and industrial problems. Incidentally it has been largely instrumental in fostering the scientific-instrument trade of the country. Research workers and manufacturers in this country have long felt the need of such a journal, for although descriptions of instruments and methods of measurement are published in the specialised journals and in the Transactions of learned societies emphasis is not as a rule laid on the construction of the instruments, nor are detailed drawings generally reproduced. Still less does one find an indication of possible applications of an instrument or method in a field other than that for which it was originally devised. Physical measurement is the basis of all exact scientific and industrial work, and a journal of the proposed scope will not only be of direct value to the research worker in physics, chemistry, engineering, biology and medicine, but it will also materially aid manufacturers of scientific instruments and act as an incentive to invention and progress. The journal will be managed by a committee appointed by the Institute of Physics on which the Department of Scientific and Industrial Research and the National Physical Laboratory will be represented, and the editorial work will be carried out at the National Physical Laboratory assisted by a scientific advisory committee appointed by the Institute of Physics. It will probably consist of 32 pages and will be published monthly at 2*s.* 6*d.* per issue. The institute will only find it possible to make itself responsible for the journal if its financial position is secured; and as a means of ascertaining what support may be expected a specimen number for free issue is now being issued. Anyone desirous of obtaining a copy of this number is asked to apply to the Secretary of the Institute of Physics, 10, Essex-street, London, W.C. 2, and to enclose 6*d.* to cover postage.

THE MECHANICAL DESIGN OF SCIENTIFIC INSTRUMENTS.*

DEFINING an "instrument" as an arrangement of co-acting parts to aid the senses during the performance of an experiment, and confining the term "scientific instrument" to that class which definitely measured some physical magnitude, Professor Pollard distinguished two main groups of instruments: Those aiding the senses in a qualitative manner and used only for observation, and those aiding the senses in a quantitative manner and used for measurement. The second group was by far the largest and most important, and represented the last stage in the natural evolution of the instrument. The laboratory instrument of to-day frequently was the tool of to-morrow. The design of scientific instruments embraced the application of many branches of the physical, engineering and chemical sciences; but as the design passed to the stages of serviceable construction, manufacture and mass production, the considerations were chiefly of a mechanical, engineering and economical nature.

Reviewing Maxwell's fundamental principles† of the construction of all instruments, Professor Pollard explained that we could relieve the pieces of an instrument from unnecessary strain, as well as secure for the fixed parts a determinate position and ensure that the movable parts should move freely, yet without shake, by attending to the well-known fact in kinematics: A rigid body has 6 degrees of freedom. Before considering that kinematical proposition we should thoroughly acquaint ourselves with what was meant by a kinematical degree of freedom.

Degrees of Freedom and Constraint.—Professor Pollard considered first a point in space. The point had no dimensions and could not enjoy rotation, therefore; it had no parts and one aspect only, *i.e.*, position when viewed from any direction. Its position had to be referred to some frame, *e.g.*, to a system of rectangular co-ordinates. The general displacement of the point could then be resolved into three motions, *i.e.*, translations along, or parallel to, the axes X, Y, Z; those were the three degrees of freedom (3 d.f.) of the point. When one of the co-ordinates was fixed, $X = a$, the point was confined in its movement to a plane parallel to Y Z, and could move in that plane, parallel to the two directions Y and Z; the point then had 2 d.f. and had imposed upon it one degree of constraint (1 d.c.). When further constrained to move on another plane by $Y = b$, the point could only move at the same time in the first and the second planes, that is, along the intersection of these two, and parallel to Z; the point now had 1 d.f. and 2 d.c. When a constant value was also assigned to the third co-ordinate, $Z = c$, the point $X = a$, $Y = b$, $Z = c$ was fixed and common to the intersection of the three planes; it had no d.f. and 3 d.c.

We did not fully understand yet, however, what was meant by a degree of freedom. We had only referred to plane surfaces; but constraint might be imposed in other ways. We might use polar co-ordinates and confine the movements to the surface of a particular sphere. That would deprive the point of 1 d.f., as it could only move in latitude and longitude on that sphere. In general a degree of constraint could be expressed by equating some function of the point's rectangular co-ordinates to a constant; that equation then represented a surface on which the point might lie; three such equations would fix the point. If the constant of any one equation were variable, then the equation would represent different surfaces of that particular family. Thus the three constants, if variables, were themselves co-ordinates of the point, and were spoken of as "generalised co-ordinates." In that sense the point had still 3 d.f. Instead of being regarded as having a degree of freedom along a straight line in space, the point had freedom over a surface, and it required three such surfaces to fix it.

Passing to the rigid body, Professor Pollard stated that a body, rigid or assumed to be rigid for the present, had dimensions and could rotate about some axis. That introduced three more degrees of freedom, and the general motion could be resolved into three rotations about the axes X, Y, Z, as well as translations along these axes, making 6 d.f. (Fig. 1). When we fixed one point of the body, it lost 3 d.f., for it could not be translated; but it could still rotate about the three axes passing through that fixed point. The body then had 3 d.f. left which, together with the 3 d.c., made up the six elements. The fixed point might in general be a point of a continuous surface of the body in contact with a continuous fixed surface; but it should be assumed that no sliding took place between the two surfaces.

This condition was realised in practice by a ball and socket joint, of which the centre was the fixed point; that joint enjoyed 3 d.f. If two points of the body were fixed, the body lost two more d.f.; for it could no longer rotate about the two axes perpendicular to the line joining the two points, but only about this latter line, and had therefore only 1 d.f. left. A third fixed point not in line with the other two, would completely constrain the body.

Now when a point of the body was fixed, we robbed it of 3 d.f.; but if we allowed the point to move in any direction over a fixed surface, we gave it back 2 d.f. Hence a body forced to move in contact with a fixed surface lost 1 d.f., *i.e.*, it could not move normally to that surface and had 5 d.f. left. Every successive constraint of a point in the rigid body to a surface meant an additional loss of a d.f., and six such conditions completely fixed the body. Thus, if six points properly chosen on the barrel and stock of a rifle were made to rest on six convex portions of a fixed support, the rifle might be replaced any number of times in precisely the same position for testing its accuracy.

Fig.1

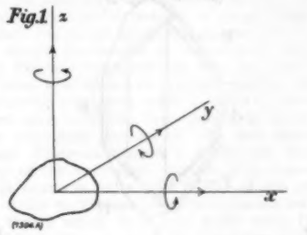
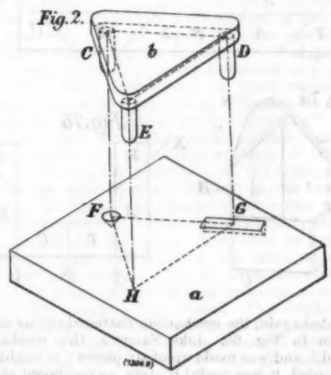


Fig.2.



Geometrical Design.—Design guided by these principles was termed "geometrical design," and we might see already that such design would in many cases eliminate accurate fitting with its troublesome tolerances and that it would reduce the number of functional surfaces to a minimum. By thus introducing the various constraints which we required in accordance with geometrical and kinematical principles we achieved good design, and could, as would be seen, reduce cost of production while retaining precision of adjustment otherwise unobtainable. The number of ways of applying geometrical design was unlimited, but that part of the subject was not so well understood as it deserved. Professor Pollard therefore devoted a good deal of his time to description of successfully-designed parts of instruments and to the examination of defects of design violating those principles.

Definite Position.—To place an instrument or part of it in a definite position, required means of applying and maintaining six mutual pressures between the part and its support touching one another at six points, an arrangement called a "geometrical clamp." In a well-known form of this, the support was supplied with three V grooves to bear the six gravity pressures produced, *e.g.*, by the legs of a theodolite. The arrangement of the surfaces was important. If one of the surfaces were removed, the corresponding point of the instrument, which now had a d.f., would move in a direction determined by the other bearings; the tangent plane at the bearing should be as nearly as possible square to the direction of this possible movement. The three grooves-device generally was not so well conditioned as Kelvin's clamp, in which one foot rested in a V, another in a trihedral hollow in line with the V groove, and the third on a plane (Fig. 2). One of the six bearing points was on the plane, two were on the sides of the groove, three on the sides of the trihedral hollow. If we substituted for gravity a spring or a light screw and nut binding the part to its support to which those six planes belonged, we had a geometrical clamp, more secure and precise than the usual three screws forced to the utmost. The trihedral hollow was difficult to make and was hence replaced by a drilled conical hole. But there was Kelvin's objection that the conical hole might not be quite true and slightly elliptic instead of circular, so that the three points of contact were reduced to two; the hemispherical foot would then not rest steadily in the hole, but might slightly be displaced horizontally along the major axis, besides the legitimate rotation about any axis through the centre of the hemispherical surface. The defect could be remedied, not by trying to turn the hollow true (when a hair or dust would cause the desired result to be lost again), but by altering the one or the other of the surfaces so as to render it manifestly not a figure of revolution; this could be done roughly by filing three round notches in the hollow so as to transform it into something between a trihedral pyramid and a circular cone, leaving the foot round, or else roughly filing three places on the foot so that horizontal sections a little above or below the points of contact might roughly be equilateral triangles with rounded corners.

By removing one of the planes we gave the parts 1 d.f., and such an arrangement was termed a "geometrical slide." Thus, if we replaced the groove in Fig. 2 by a plane, so that two feet rested on the plane while the third remained in its hollow, we had a "slide." The first application of this form of slide, in which the single d.f. was rotation about a vertical axis, was Kelvin's azimuth mirror, an instrument placed on the glass cover of a compass to take the azimuth of the sun or of stars in order to correct the compass. By loading the instrument so that its centre of gravity was nearly over the foot resting in the hollow, the movement could be made very frictionless when the plane was horizontal. The familiar support of telescope trunnions in V-shaped bearings, when end long motion was prevented, was another example of the geometrical slide.*

Turning Pair.—This movement between the two pieces was precisely that of a journal in its bearing and similar to that of a "turning pair" of mechanism. The extensive surfaces of contact in the turning pair of mechanism between the cylinder and its hole had been replaced by point contacts on five surfaces. The tolerances necessary for the sliding fit were frequently responsible for a peculiar type of hysteresis (to which the lecturer reverted later). That hysteresis error was the greater, the greater the want of good fit, and good fit in turning pairs for manufacture in quantity required the upkeep of limit gauges. The geometrical slide was kinematically exact and free of variance, and its manufacture could be effected at a minimum cost without limit gauges. The five surfaces against which five points of the movable body were pressed could be so arranged that the single d.f. left was one of translation (instead of rotation), *e.g.*, by removing one of the planes in the hollow of Kelvin's hole, slot, and plane and converting it into a V-groove parallel to or, better, in line with, the other groove. This design was applied in the mechanism for moving the fourth quadrant of Kelvin's electrometer and in some of the models of the Cambridge and Paul Instrument Company.

Professor Dalby had applied the V-shaped grooves resting upon a cylindrical rod in order to give easy and smooth movement to a pulley in his dynamometer (Fig. 3, page 730). The grooves V_1 and V_2 were part of the casting A which housed the pulley; this gave four surfaces of contact on the rod. The other surface was at A_1, bearing on a second rod parallel to the first. At R a lever was hinged to the casting which, by being forced against a third rod by means of a spring attached to the casting, maintained the necessary pressures between the five surfaces V_1, V_2, A_1 and the rods. In the magnificent Einthoven string galvanometer of the Cambridge and Paul Instrument Company†) the carriage carrying the fibre was supported by the hole, slot and plane. Mr. Mallock's vibrograph‡ was another ingenious application of geometrical design. The simplicity and cheapness of all these forms of geometrical design were due to the fact that the constraint was produced by the pressure of a point against a surface; at the most only one of the elements of the constraint had to be worked carefully, and the worked surface as a rule took the form of a cylinder or plane which need only be ground for most purposes.

When the pressure was too great for one point, the design could frequently be pushed to more than one point of contact for a given constraint. But when we did this, the geometrical principle was violated, and we had at once to introduce accurate and more expensive manufacture. Cylinders, planes and spheres

* Abstract of three Cantor Lectures, delivered in February and March last before the Royal Society of Arts by Professor Alan F. C. Pollard, A.M.I.E.E., F.Inst.P., Department of Optical Engineering, Imperial College of Science and Technology, South Kensington.

† We would refer our readers to Mr. R. H. Whipple's presidential address to the Optical Society, see ENGINEERING, May 27, 1921, pages 659 to 662, as to these principles and also as to some of the models and devices of which Professor Pollard made use in his exposition.

* Compare also Fig. 1, page 660, *loc. cit.*

† ENGINEERING, August 22, 1919, page 253.

‡ ENGINEERING, May 27, 1920, page 661, Fig. 9.

could accurately and cheaply be manufactured, however, and the construction of instruments greatly be simplified by this compromised geometrical design. A good example of this was shown in the use of the sphere, cylinder and plane for the slide of the carriage of Messrs. Alfred Herbert's universal dividing machine.* If still greater pressures had to be taken, the point contact could be made a plane contact; that would increase the difficulties of production, however, for the surfaces of constraint were now true component functional surfaces which had to fit accurately in all positions of the moving piece. The ordinary V and plane of the bed of a lathe for the traverse of the saddle and loose headstock offered a familiar exemplification.

Frictional Aberration.—Frequently extremely accurate slide motion had to be combined with a minimum of frictional resistance for parts, either of considerable weight or subjected to large separating forces. Professor Pollard had known cases in which instruments had had to be abandoned because excessive force was required to set the pieces in motion with consequent aberration in the recording mechanism

Fig. 3.

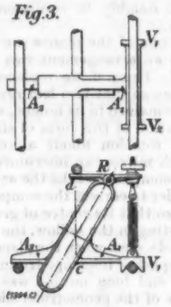


Fig. 4a.

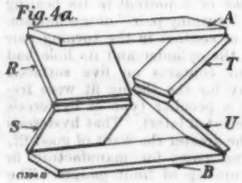


Fig. 4b.

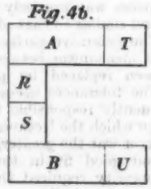
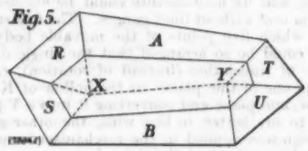


Fig. 5.



and undesirable wear. The question arose whether the sliding pair could be entirely replaced by turning pairs, and he thought that a general answer could be found in Sarrut's mechanism.

Sarrut's Mechanism. Bennett's Modification.—The production of a straight-line motion had been believed impossible until Peaucellier solved the problem by the invention of his inverting cell. Sarrut had, however, solved the more complete problem (*Comptes Rendus*, 1853, vol. xxxvi) eleven years before Peaucellier. All the straight-line motions of devices of the Peaucellier type gave that motion to all the points of a line in one of the pieces parallel to the hinge lines, or else to all the points of a hinge line connecting two pieces. Sarrut's solution (Fig. 4*a* and *b*) gave rectilinear translation to a whole piece. The pieces A and B were connected together by the four pieces R, S, T, U; R and S themselves being joined with one another and with A and B by means of three parallel horizontal hinges, while T and U were similarly connected by three other parallel and horizontal hinges, differing in direction from the first hinges. Thus A would have a rectilinear motion with respect to B and, what was constructionally important, A and B remained strictly parallel throughout the whole motion. If therefore A represented a part of an instrument required to slide with regard to the frame B, the sliding pair could be replaced by wholly-turning pairs represented by the hinges in the model [shown]. When the hinge T U was disconnected, the mechanism flattened out as indicated in plan in Fig. 4*b*.

Sarrut's mechanism was not appreciated for fifty years until Bennett generalised upon it in 1905. The generalisation, though not of much practical utility at present, would no doubt play an important role in the instrument design and in the machine design of the future—and has, indeed, we may add, been adopted by one instrument maker who had listened to Professor Pollard's lectures. Bennett pointed out that, as seven was the normal number of pieces in a closed kinematic chain necessary to ensure freedom of 1 deg., the mechanism of Sarrut belonged to a special class of mechanism with only six pieces possessing singularly and exceptionally 1 deg. of freedom. In Bennett's mechanism (Figs. 5, 6*a*, 6*b*) of which Sarrut's was a special case, the pieces A and B were interconnected by R, S, T, U, as before; but if the axes of the hinges connecting A, R, S, B, met at X, and the axes of the hinges connecting A, T, U, B, met at Y, then the piece A would have a motion of pure rotation relative to B about the line X Y. When the hinge T U was disconnected again, the mechanism flattened out as shown in plan in Fig. 6*b*. Like Sarrut's, this mechanism had 1 d.f. and was made up of six pieces; it might also be regarded, it was useful to note, as composed of two spheric mechanisms, each of four pieces placed in tandem, with different centres. If now the hinges connecting A, R, S, B, and those connecting A, T, U, B were made parallel (Figs. 4*a* and *b*), the points X and Y went to infinity, and the piece A rotated relatively to B about an axis at infinity, *i.e.*, A had rectilinear motion relative to B, and Sarrut's mechanism was the result. When only one of the points, say Y, was sent to infinity, by making the hinges of A, T, U, B parallel, we obtained a third mechanism in which A rotated relatively to B about a line parallel to the hinges of A, T, U, B, and passing through the point X, the intersection of the other hinges (Fig. 7*a*). After disconnecting the hinge R S, the mechanism would again flatten out, as shown in Fig. 7*b*.

Fig. 6a.

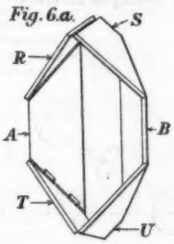


Fig. 6b.

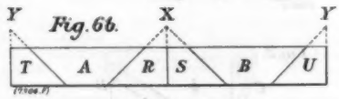


Fig. 7a.

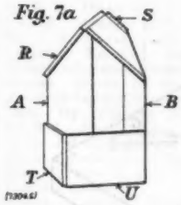
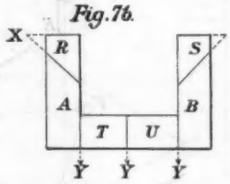


Fig. 7b.



Although Sarrut's invention was not generally known even now, it had not escaped the fate of all inventions and had been re-invented more than once; Brunel patented it in 1880, and Professor Archibald Barr reinvented it in 1891 (Proc. Phil. Soc., Glasgow, March 18, 1891).

(To be continued.)

NOTES ON NEW BOOKS.

TECHNICAL Record No. 8 of the Explosives Supply, 1915–18, is in one respect rather disappointing. The title "*Solvent Recovery*" is as promising as that of any of these volumes. The solvents used in the industries of explosives, rubber, &c., viz. alcohol and ether, acetone, benzene, carbon disulphide, &c., not rarely represent one of the heaviest items in the cost of production, and efficient recovery is generally desirable as well in the interests of safety and hygiene. But this Record, No. 8 (H.M. Stationery Office, Imperial House, Kingsway, W.C. 2; price 3*s.* 3*d.* post free), one of the volumes in neat grey cardboard, published by the Ministry of Munitions and the Department of Scientific and Industrial Research, confines itself in its 22 pages entirely to the recovery of the alcohol and ether as used in the cordite manufacture at Gretna. One would like to have a good deal more in the volume. Some of the research work was done at Woolwich and in Messrs. Nobel's works, and this is also noticed. At Gretna alcohol and ether are mixed with the cordite paste; the dough is carried to the press-house, extruded, &c., and the strands are taken in trays to the recovery stoves, in which the solvent vapours are liberated by air heated to 30 deg. C. for about 40 hours. The escaping vapours pass first through traps to catch any spray of nitroglycerin, and are then sent into scrubbers in which the vapours are absorbed. The absorbent first used was sulphuric acid (Barbet's process); this was replaced by water, because the acid does not take up the ether, and is only slightly superior to water as regards the alcohol; finally cresol was used (Bregeat's process). The rotary Whessoe scrubbers were utilised, and part of the original acid absorption plant remained available for the final process. The cresol gives up the solvent again on being heated in stills by steam in coils at 50 lb. pressure; the recovery reached 65 per cent. of the theoretical. The details given are all very interesting; but the limitations of the contents might have been pointed out on the title page, or something else have been added to the volume.

Measurement of gases in bulk is frequently shirked in practice. The ordinary revolving gas meter becomes expensive when it has continuously to measure large volumes of gases, especially when they are hot or acid or carry much dust. For this reason the actual volumes of producer and blast-furnace gas, used in the metallurgical and ceramic industries, and the masses of air sent into coke ovens or required simply for drying and ventilation, are not determined though it might be advantageous to do so. But we are not restricted to one method of gas-volume measurement. We may rely upon the velocity of flow determined by the aid of anemometers or hydrostatic balances; we may measure the resistance which the flowing gas experiences in nozzles and Venturi tubes; and we may resort to calorimetric and chemical methods. Each of these methods has a literature of its own, mostly, however, in the shape of papers. We do not know of any recent comprehensive treatise on the whole subject like the "*Messung Grosser Gasmengen*," by L. Litinsky (Leipzig: Otto Spamer). This volume of 274 pages belongs to the Chemische Technologie series of monographs, originally edited by Professor Ferdinand Fischer and now edited by Professor A. Benz. The object of the author, an engineer, is technological; the theory is kept short, tables and curves are given, practical examples are worked out, and a good literature list and subject matter and name indexes are provided. Descriptions are given, among others, of the new registering apparatus of the Hydro-Apparat Bauanstalt P. de Bruyn and of R. Fuess, of the Skala and Rota meters, in which conical floats are raised and turned, and the calorimetric meters of Carl Thomas (Wisconsin). Katharometers and apparatus of McGregor Morris and of J. S. G. Thomas are not referred to; but they are hardly appliances for large-volume determinations, and though German instruments naturally predominate, English inventions are not overlooked.

If power alcohol is still more talked about than used as a fuel, it is not the lack of literature on the subject which prevents the technical development. The most recent contribution to this literature, "*Power Alcohol, its Production and Utilisation*," by Dr. G. W. Monier-Williams, M.A., F.I.C. (London: Henry Frowde and Hodder and Stoughton, 1 and 2, Bedford-street, W.C. 2; price 21*s.* net), is a good volume (of 323 pages) upon which considerable time and study have been spent by a writer of experience. Each of the chapters has its own bibliography, that on synthetic alcohol alone comprising 41 items. That the engineer's side of the problems only comes in with Chapter VIII—there are XI chapters altogether—is partly due to the fact that alcohol still remains a material for the chemist and distiller rather than for the engineer. Even synthetic alcohol does not advance much, however, though the synthesis from ethylene, we see, goes back to Hennell and to 1828, the date generally assigned to Woehler's first synthesis of an organic compound, and the manufacture, during the war, of acetone and acetic acid from acetylene in this country came to an end with the war, nor does it seem to prosper elsewhere. We also read that the inclusion of alcohol, and possibly of ether and other bodies, in fuel mixtures will introduce many difficulties in the way of analytical procedure, and that it is also difficult to obtain reliable data on the corrosion of cylinders and other parts by the combustion products of alcohol. The non-deposition of carbon from alcohol on pistons and heads of engine cylinders, is important, and not only because the engines are kept clean inside. As Dr. Monier-Williams says; the soot favours over-heating of the piston head.

*We illustrated this Wickman machine of Messrs. A. Herbert in our issue of September 17, 1920, on pages 330, &c.; Professor Pollard drew particular attention to the support of the main carriage on steel rollers and bars, so arranged as to form a V-guide—features explained by our Figs. 127, 128, 131 to 133.

If, however, alcohol is apt to cover the inlet-valve pockets with a tarlike or gelatinous deposit, as Mr. Monier-Williams states, there is not much gained, and the chemist has yet by no means done with power alcohol.

The days are, perhaps, not wholly passed when the hierarchy responsible for the conduct of educational training viewed with disapproval the introduction of laboratory and practical instruction into the unchanging curriculum that they periodically presented to their students. But an ever growing number of authorities, desirous that some training in the methods of research should be provided and encouraged, have overcome the extreme conservative attitude, and the use has been rather grudgingly sanctioned in some quarters, of a syllabus which permits the pupil to indulge in the wearying measurements of distances, volumes, relative densities and similar uninteresting work—exercises that tend to increase, if they do not explain, the present day indifference to science in this country. Further attacks against this marked dislike exhibited by the adherents to a past tradition, have led to the appearance of many excellent text-books on laboratory practice, placing at the command of those who desire to acquire or impart an intelligent acquaintance with the mechanical, electrical and other processes, facilities and suggestions for the employment of apparatus whose practical use will introduce new life and interest. Such a work is that on "*Practical Physics*," by Messrs. Bower and Satterly (London: University Tutorial Press, Limited, price 7*s.* net), now a second edition, thus affording evidence of its value, for it has to compete with numerous and later rivals. The treatment of the subject naturally follows the same lines as the earlier edition, for an author's opinion of the educational value of an experiment does not alter with time. Experience and fashion may make some additions expedient, and the author has, so far, conformed to the demands of a varying standard, that he has added a supplement, outlining experiments on friction, acceleration, surface tension, thermal expansion and conductivity, &c. But these additions wear the appearance of an excrescence and do not fall easily into the general scheme, devised by the authors, one of whom, Mr. Satterly, appears to have withdrawn from the collaboration.

The scheme provides for the measurement of certain physical quantities by those who have acquired some knowledge of physics, but have attempted no practical work in the laboratory. The authors regard the handbook as a complete elementary manual of the subject, affording practice in the elementary principles of measurement, and also in the setting up of apparatus that permits the investigation of fundamental principles of heat, sound, light, electricity, &c. Without subscribing completely to this view, it may be said that within the limits of the treatise the authors have fulfilled their programme. The experiments are varied and well selected, wide teaching experience being evidenced by omissions as well as by the examples provided; one would like to suggest extensions in several directions, but we have no doubt the authors have exercised a wholesome restraint. The addition of a number of experiments that can be performed at home is an excellent feature. Not only is such practice valuable to those whose opportunities for work in fully equipped laboratories are small, but is calculated to make the student more self-reliant, and to lead him to vary the conditions of experiment in a way that he would be too self-conscious to attempt when surrounded by students. Moreover, the authors encourage the tyro to construct his own apparatus, and not only does such procedure facilitate deftness of manipulation, but more is to be learnt from the roughest of self-constructed apparatus, though it give large errors of observation, than from more costly instruments whose purpose is imperfectly understood and of whose delicacy the student cannot take full advantage.

When Dr. Wilhelm Jaeger wrote his treatise on the technics of electric measurements in 1917, he struck practically new ground. There were some books, though not many of merit, on methods of measurements and the principles of the instruments, among which the "Praktische Physik," by Dr. Jaeger's chief, President Kohlrausch, of the Physikalisch-Technische Reichsanstalt, ranked first. But these books were either rather guides for experimenters, or descriptions of the special instruments of some class, and they did not deal broadly with the general principles underlying the design of electric measuring instruments of various types. As one of the senior members of the Reichsanstalt Dr. Jaeger was exceptionally qualified for this general task, and by 1921 a second edition of his "*Elektrische Messtechnik. Theorie and Praxis der Elektrischen und Magnetischen Messungen*" was called for. This second edition (Leipzig: Johann Ambrosius Barth; price 165 marks, bound) is of nearly the same compass as the first edition, but the 528 large octavo pages, illustrated by 581 text figures, contain a great deal of new matter. The first two sections of the volume are devoted to theoretical foundations and to units and standards; the first 20 pages on vector analysis might have been omitted, though the advantages of vector methods are now generally acknowledged. The other sections deal with electric (direct and alternating currents) and magnetic measurements and with the measurements depending on temperature changes and radiations. The details of the routine testing of dynamos and motors and of high-frequency radiotelegraphic measurement Dr. Jaeger rightly leaves to special treatises. The carefully compiled names and subject-matter index of 25 pages deserves mention.

It is somewhat noteworthy that such French text-books on mechanical engineering as have come under our notice in recent years, appear to be far more satisfactory on the practical than on the theoretical side. "*Turbines a Vapeur*," par M. Poincet, Professeur à l'Eole d'application du génie maratime, which has recently been issued by the Libraire J.-B. Ballière et Fils, Paris, at the price of 35 fr., forms no exception to this rule. M. Poincet is far from a safe guide on questions of hydraulics and thermodynamics, but his book contains much information of considerable practical value. As to the properties of steam, he appears still to accept the results of Regnault as standard, although Regnault's magnificent work was carried out in the 'fifties and 'sixties of the last century, and has, by more recent researches made possible by the better apparatus now available, been proved to be in need of some important corrections. He also seems still to accept Professor Rateau's conclusion that the efficiency of the convergent portion of a convergent-divergent nozzle is unity. In excuse of the author's neglect of the very important developments on steam turbine theory which have been made since 1912, it is only fair to bear in mind the intensity of the war strain in France, which may well have made it impossible for M. Poincet to keep abreast of the times. This plea will, however, hardly serve as apology for the fallacy concerning the impact of a fluid jet on a plate, which is embodied in the statement on page 281 that "si le fluide était dénué de toute viscosité, la veine se réflecherait sur la face d'impact en faisant un angle de réflexion égal à l'angle d'incidence." Even the perfect fluid of the pure mathematician would not bound back from a plate with an angle of reflection equal to the angle of incidence. By the destruction of some of the momentum of the fluid at the surface of the plate a pressure is created there. But when a pressure is exerted on a fluid it is necessarily the same in all directions, and hence momentum is generated by this pressure tangential to the plate as well as perpendicularly thereto. For M. Poincet's statement to be correct the pressure should generate momentum only in the direction last named. This fundamental fallacy vitiates much of the author's discussion of the interaction between the working fluid and the blading of a turbine. His neglect of the phenomenon of supersaturation has led him, moreover, to deduce a "velocity coefficient" for Parsons blading of but 0·67. If the data he has studied had been obtained with highly superheated steam he would have found a far higher value. An analysis made by the method of least squares of a series of progressive trials of a turbine tested under laboratory conditions with steam superheated throughout has yielded the value 0·875 for the nozzle (energy) efficiency of Parsons blading and the value 0·80 as the fraction of the kinetic energy discharged from the blading, which is effective in promoting flow through the next row. The corresponding velocity coefficient is therefore nearly 0·90. We have noted these points because we believe that on the practical side M. Poincet's work will be found of considerable use to designers. He gives many data as to the standard practice of the French Navy and a number of practical semi-empirical rules for determining the general proportions of a turbine, to yield a given output at a stated speed. Considerable space is, moreover, devoted to the discussion of the auxiliary machinery.

We have frequently noted that once a student of engineering has been taught to calculate he frequently ceases either to observe or to think. He places the same reliance on his formulas as the school men of the past did on the authority of Aristotle as the one sure guide to natural phenomena. Sun spots were impossible because the sun being the symbol of perfection could not in the very nature of things suffer from such blemishes, and similarly structures of a type which have given excellent and economical service for years are at times condemned on the strength of certain formulas. Such formulas necessarily contain an empirical factor, and must therefore be subject to correction in the light of accumulated experience. By many computers, however, the authority of the formula is accepted as final just as was that of Aristotle three or four centuries ago. From Professor C. A. Ellis's preface to his treatise on the "*Essentials of the Theory of Framed Structures*," just published by the McGraw-Hill Book Company, Inc., at 17*s.* 6*d.* net, it would appear that the state of things criticised above obtains also in America, where Professor Ellis says "there is a growing tendency in engineering schools to instruct rather than to educate," with the result that the students learn to apply formulas without really grasping the principles on which they are based. In the work under review Professor Ellis has followed a different line, and endeavoured to make clear the basic principles of the theory of framed structures. We learn that the author was designing engineer for the Dominion Bridge Company from 1912 to 1914, having previously had several years' experience with the American Bridge Company, so that he is well equipped for his task.

As is well known, our present division of the right angle into 90 deg. and of each degree into minutes and seconds is an inheritance from the Chaldean astronomers, and a very inconvenient legacy it has proved. The opportunity of supplanting this awkward system of angular measurement arose with the invention of logarithms by Napier, and Briggs who bore the main burden of computing the new tables, had with characteristic common sense arranged to seize the occasion and prepare trigonometrical logarithmic tables based on the decimal system. Unfortunately, Adrian Vlacq, who shares with Briggs the honour of providing the basis of all the logarithmic tables in common use, though he himself modestly disclaimed the credit which was fairly his due, appears to have been unaware of this intention, and at any rate he published logarithmic tables of the trigonometric functions based on the old sexagesimal system, and Briggs accordingly abandoned the idea of effecting a reform. There have been several attempts to effect a change since, but habit has so far proved too strong. A new set of tables for angles divided on the decimal system has just been published by Messrs. Gauthier-Villairs et Cie., Paris, under the title "*Tables centesimales pour le tracé des courbes*," and is priced at 15 fr. The author is M. J. Bouchard, who has had particularly in view the needs of civil engineers and surveyors. The tables give the natural trigonometric fractions to six places of decimals, and will be found extremely useful by the increasing number of surveyors who are using instruments divided on the decimal system.

When the Petroleum Exhibition was held in 1920 at the Crystal Palace, the Institution of Petroleum Technologists arranged for a series of lectures intended to give the general public information and guidance concerning the production, refining, transport and uses of petroleum. The instructive character of the lectures finding appreciation, the Council of the Institution decided to publish the course in the form of a book entitled "*The Petroleum Industry.*" [The Institution of Petroleum Technologists, 5, John-street, Adelphi, W.C. 2, price 14*s.* 6*d.* net.] The octavo volume of 350 pages comprises also statistics, and very welcome notes on nomenclature, a list of text-books, and an index. Dr. A. E. Dunstan has acted as editor. We noticed several of these lectures at the time, as well as the discourse on "The Romance of Petroleum," which was delivered by the late Sir Boverton Redwood at the Royal Institution in June, 1918, and a résumé of which is also reprinted in this volume. The contributors are: Sir F. W. Black, Messrs. E. H. Cunningham-Craig, G. Howell, Herbert May, H. Barringer, A. E. Dunstan, F. B. Thole, W. R. Ormandy, J. S. S. Brame, J. Kewley and A. W. Eastlake. Popular surveys of this type, compiled by real experts, are always acceptable.

STANDARD GRAPHICAL SYMBOLS FOR ELECTRICAL PURPOSES.—Publication No. 108, 1922, of the British Engineering Standards Association, which has just been issued, contains the first list of British standard graphical symbols for use in electrotechnics, and is the result of co-operation between various Government departments, technical societies, industrial organisations and experts interested in the subject. The list contains nearly 900 symbols divided into eight sections relating to power stations, transmission, machines, switch gear, instruments, resistances, &c., telegraphs and telephones, radio communication, and traction, and while admittedly incomplete it is thought that the list will meet a long-felt want in view of the fact that so many organisations at present use their own particular symbols, thus causing considerable confusion. In connection with export work the symbols should be particularly useful, a large number of them being in agreement with those used in other countries. The list will be subject to periodical revision, and provision has been made for additions, but in the meantime it is urged that every engineer should make use of the list and thus assist the work of the association, whose endeavour has been to make the list acceptable to every branch of the industry. Copies of the publication can be obtained from the offices of the association, at 28, Victoria-street, London, S.W. 1, price 1*s.* 4*d.* post free.

SOME SPECIAL CASES OF TWO DIMENSIONAL STRESS OR STRAIN.*

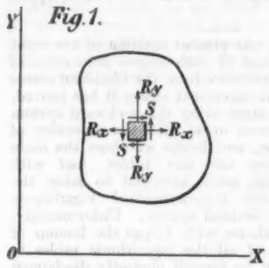
By Professor C. E. INGLIS, M.A., Associate.

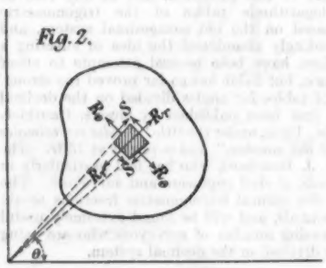
SUPPOSE that positions on a thin flat plate (see Fig. 1) are defined by co-ordinates x, y, referred to rectangular axes drawn in the plane of the plate. If the plate is stressed by forces applied along the boundary of the plate in directions parallel to the plane of x y, it is well known that the three stress components R_x, R_y, S, which completely specify the stress at a point, are given by :—

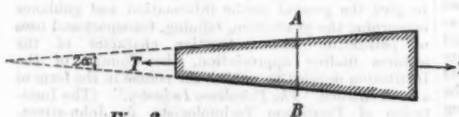
$$R_x = \frac{\partial^2 V}{\partial y^2}, \quad R_y = \frac{\partial^2 V}{\partial x^2}, \quad S = -\frac{\partial^2 V}{\partial x \partial y}$$

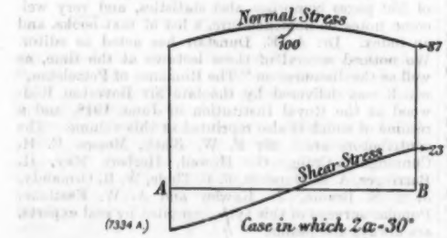
where V satisfies the differential equation :—

$$\frac{\partial^4 V}{\partial x^4} + 2\frac{\partial^4 V}{\partial x^2 \partial y^2} + \frac{\partial^4 V}{\partial y^4} = 0$$









In the following discussion the shapes dealt with are sectors of circles, and with this object in view it is desirable to transform the above results into polar notation. Effecting this transformation, it will be found that the three stress components R_r, R_θ, S (see Fig. 2), are given by :—

$$R_r = \frac{1}{r^2}\frac{\partial^2 V}{\partial \theta^2} + \frac{1}{r}\frac{\partial V}{\partial r}$$

$$R_\theta = \frac{\partial^2 V}{\partial r^2}$$

$$S = -\frac{1}{r}\frac{\partial^2 V}{\partial r \partial \theta} + \frac{1}{r^2}\frac{\partial V}{\partial \theta}$$

where V, in this case, is found from the differential equation :—

$$\left(\frac{\partial^2}{\partial r^2} + \frac{1}{r}\frac{\partial}{\partial r} + \frac{1}{r^2}\frac{\partial^2}{\partial \theta^2}\right)\left(\frac{\partial^2 V}{\partial r^2} + \frac{1}{r}\frac{\partial V}{\partial r} + \frac{1}{r^2}\frac{\partial^2 V}{\partial \theta^2}\right) = 0.$$

A general solution of this equation is :—

$$V = (A\, r^n + B\, r^{n+2}) \cos n\,\theta$$

and from this the following general stress components can be deduced :—

$$R_r = -[A\, n\,(n-1)\, r^{n-2} + B\,(n-2)(n+1)\, r^n] \cos n\,\theta$$

$$R_\theta = [A\, n\,(n-1)\, r^{n-2} + B\,(n+2)(n+1)\, r^n] \cos n\,\theta$$

$$S = [A\, n\,(n-1)\, r^{n-2} + B\, n\,(n+1)\, r^n] \sin n\,\theta$$

Another set of stress components can be derived by writing $\cos n\,\theta$ in place of $\sin n\,\theta$ and $-\sin n\,\theta$ in place of $\cos n\,\theta$. In the above formula n can be any number, whole or fractional, positive or negative, while A and B are arbitrary constants to be decided by the particular nature of the boundary conditions. In the foregoing analysis the plate is assumed to be so thin that no appreciable shear stress or normal stress in a direction at right angles to the plane surface has room to develop, the stress in effect being purely two-dimensional in character. In the case of a plate of great thickness, if the stresses applied to the boundary are uniformly distributed in the direction of the depth of the plate, then, except near the top and bottom plane surfaces, the state of strain does not vary with the depth, and the expressions for R_r, R_θ, S stated above can be used to determine the state of stress in the plate, excluding only regions near the free plane surfaces.

It is now proposed to deduce from the general stress formulæ certain particular stress distributions relating to a flat of tapering width. The converging sides are supposed to be inclined together at an angle 2 α, and the thickness of the flat is supposed to be t (see Fig. 3).

Case 1.—In the general formulæ put $n = 1$ and make $A\,(n-1) = \frac{P}{4}$; this means that A has to be indefinitely large of the order $\frac{1}{n-1}$

Then

$$R_r = -\frac{P\cos\theta}{4r}, \quad R_\theta = \frac{P\cos\theta}{4r}, \quad S = \frac{P\sin\theta}{4r}$$

is a possible stress distribution. Put $n = -1$ and make $B\,(n+1) = \frac{P}{4}$; this means that B has to be indefinitely large of the order $\frac{1}{n+1}$

Then

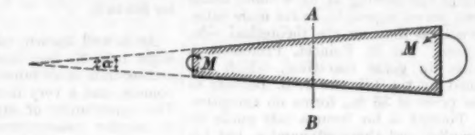
$$R_r = \frac{3P\cos\theta}{4r}, \quad R_\theta = \frac{P\cos\theta}{4r}, \quad S = \frac{P\sin\theta}{4r}$$

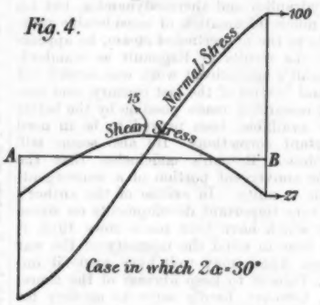
is another possible stress distribution. Neutralising one of these distributions by means of the other, the R_θ and S stress components cut out, leaving a purely radial stress distribution * defined by :—

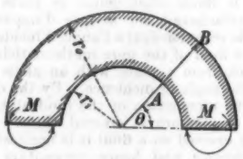
$$R_r = \frac{P\cos\theta}{r}$$

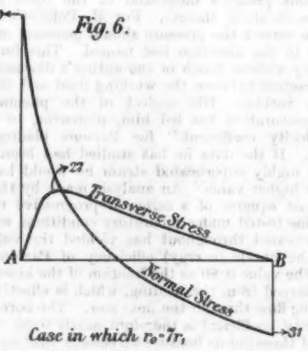
On integrating, it will be found that the total pull over any cross-section such as A B (see Fig. 3) is $P\,t\,(\alpha + \frac{1}{2}\sin 2\,\alpha)$. Hence it follows that, in the case of a taper flat subjected to an axial pull T, the stress distribution is defined by

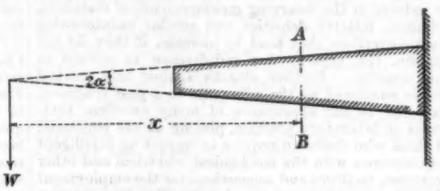
$$R_r = \frac{T\cos\theta}{t\,(\alpha + \frac{1}{2}\sin 2\,\alpha)\,r}, \quad R_\theta = 0, \quad S = 0$$

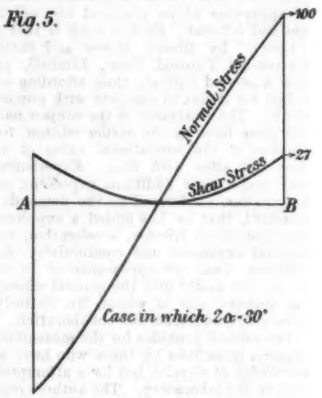


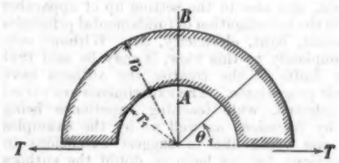


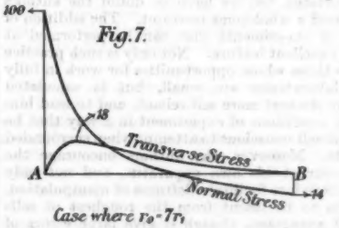












For the particular case $2\,\alpha = 30$ deg., the distributions of normal stress and shear stress over a cross-section are in accordance with Fig. 3.

Case 2.—This relates to the bending of a flat of tapering width by couples applied at its ends acting in the plane of the plate (see Fig. 4). If in the general stress formulæ n is made zero, the following stress distribution can be evolved :—

$$R_r = 0, \quad R_\theta = 0, \quad S = -\frac{P\cos 2\,\alpha}{r^2}$$

Putting $n = -2$, the following stress distribution emerges :—

$$R_r = -\frac{2P\sin 2\,\theta}{r^2}, \quad R_\theta = 0, \quad S = \frac{P\cos 2\,\theta}{r^2}$$

A superposition of these gives the stress distribution :—

$$R_r = -\frac{2P\sin 2\,\theta}{r^2}, \quad R_\theta = 0, \quad S = \frac{P(\cos 2\,\theta - \cos 2\,\alpha)}{r^2}$$

In this case the boundaries $\theta = \pm\alpha$ are free from normal and shear stress, and on integrating it will be found that the total action over any cross-section A B (see Fig. 4) is a pure bending moment of magnitude

* Paper read before the Institution of Naval Architects, April 7, 1922.

* This radial distribution of stress is referred to in Love's "Theory of Elasticity."

$P t [\sin 2\alpha - 2\alpha \cos 2\alpha]$. Putting $M = P t [\sin 2\alpha - 2\alpha \cos 2\alpha]$ it follows that in the case of the taper flat shown in Fig. 4 bent in its own plane by terminal bending moments M, the stress distribution is defined by :—

$$R_r = -\frac{2M \sin 2\theta}{t[\sin 2\alpha - 2\alpha \cos 2\alpha] r^2}, \quad R_\theta = 0,$$

$$S = \frac{M[\cos 2\theta - \cos 2\alpha]}{t[\sin 2\alpha - 2\alpha \cos 2\alpha] r^2}$$

Fig. 4 also gives the general character of the normal stress and shear stress over a cross-section for the particular case $2\alpha = 30$ deg.

Case 3.—This case is depicted in Fig. 5. It relates to the bending of a flat of tapering width by means of a transverse force. By a method of deduction similar to that followed in Case 1, the stress distribution $R_r = \frac{P \sin\theta}{r}$, $R_\theta = 0$, $S = 0$ is derived. The total action over any cross-section A B for this distribution amounts to a shearing force $P t [\alpha - \frac{1}{2} \sin 2\alpha]$, combined with a bending moment couple $P x t [\alpha - \frac{1}{2} \sin 2\alpha]$, where x is the distance of A B from the point of intersection of the converging sides. Putting $P t [\alpha - \frac{1}{2} \sin 2\alpha] = W$, the case represented in Fig. 5 is obtained, and the corresponding stress distribution is :—

$$R_r = \frac{W \sin\theta}{t[\alpha - \frac{1}{2}\sin 2\alpha] r}, \quad R_\theta = 0, \quad S = 0$$

For the particular case $2\alpha = 30$ deg., the distribution of normal and shear stress over a cross-section is in accordance with Fig. 5.

Case 4.—By combining cases 2 and 3, the general case of bending by concentrated transverse loads is obtained.

If at any particular section taken in a region which is free from any of the applied loads, the shear is **S** and the bending moment is M, then the stress distribution for this region (except in the immediate neighbourhood of the applied loads) is given by :—

$$R_r = -\frac{2[M - \mathbf{S}x] \sin 2\theta}{t[\sin 2\alpha - 2\alpha \cos 2\alpha] r^2} - \frac{\mathbf{S} \sin\theta}{t[\alpha - \frac{1}{2}\sin 2\alpha] r},$$

$$R_\theta = 0,$$

$$S = \frac{[M - \mathbf{S}x][\cos 2\theta - \cos 2\alpha]}{t[\sin 2\alpha - 2\alpha \cos 2\alpha] r^2}$$

where x is the distance of the particular section from the point of intersection of the converging sides. By a suitable choice of n in the general stress formulæ, the case of bending by means of loads uniformly or non-uniformly distributed can be similarly treated.

Case 5.—Consider now the arrangement depicted in Fig. 6, in which a curved beam of uniform depth is subjected to bending by means of couples terminally applied. In this case (except near the points of application of the couples) the state of stress and strain does not vary from section to section, and for this region the stress function V must be independent of θ.

V is accordingly to be found from the equation :—

$$\left(\frac{\partial^2}{\partial r^2} + \frac{1}{r}\frac{\partial}{\partial r}\right)\left(\frac{\partial^2 V}{\partial r^2} + \frac{1}{r}\frac{\partial V}{\partial r}\right) = 0$$

and the general solution of this equation takes the form :—

$$V = A + B r^2 + C \log r + D r^2 \log r$$

The corresponding stress components are :—

$$R_r = (2B + D + \frac{C}{r^2} + 2D \log r,$$

$$R_\theta = (2B + 3D) - \frac{C}{r^2} + 2D \log r,$$

$$S = 0$$

Adjusting the constants of integration so that R_r is zero at the top and bottom boundaries $r = r_0$ and $r = r_1$, the stress components take the following forms :—

$$R_r = P\left[1 - \frac{(r_0^2 - r_1^2)\log r + \frac{r_0^2 r_1^2}{r^2}\log\frac{r_0}{r_1}}{r_0^2 \log r_0 - r_1^2 \log r_1}\right]$$

$$R_\theta = P\left[1 - \frac{(r_0^2 - r_1^2)(1 + \log r) - \frac{r_0^2 r_1^2}{r^2}\log\frac{r_0}{r_1}}{r_0^2 \log r_0 - r_1^2 \log r_1}\right]$$

$$S = 0$$

On integrating it will be found that the stresses across a radial section combine to give a pure bending moment of magnitude

$$\frac{P t \left\{\left(r_0 r_1 \log\frac{r_0}{r_1}\right)^2 - \left(\frac{r_0^2 - r_1^2}{2}\right)^2\right\}}{r_0^2 \log r_0 - r_1^2 \log r_1}$$

where t is the thickness of the curved beam. If this pure bending moment is denoted by M, the corresponding stress components take the form :—

$$R_r = \frac{M}{t}\left[\frac{r_0^2 \log r_0 - r_1^2 \log r_1 - (r_0^2 - r_1^2)\log r - \frac{r_0^2 r_1^2}{r^2}\log\frac{r_0}{r_1}}{\left(r_0 r_1 \log\frac{r_0}{r_1}\right)^2 - \left(\frac{r_0^2 - r_1^2}{2}\right)^2}\right]$$

$$R_\theta = \frac{M}{t}\left[\frac{r_0^2 \log r_0 - r_1^2 \log r_1 - (r_0^2 - r_1^2)(1 + \log r) + \frac{r_0^2 r_1^2}{r^2}\log\frac{r_0}{r_1}}{\left(r_0 r_1 \log\frac{r_0}{r_1}\right)^2 - \left(\frac{r_0^2 - r_1^2}{2}\right)^2}\right]$$

$$S = 0$$

As r_1 decreases, the value of R_θ at the small inside radius approximates to the value $\frac{8M \log r_1}{t r_1^2}$, and consequently tends to become infinite in the case of a sharp right-angled bend. For the particular case $r_0 = 7 r_1$ the distribution of normal and shear stress over a radial cross-section is in accordance with Fig. 6.

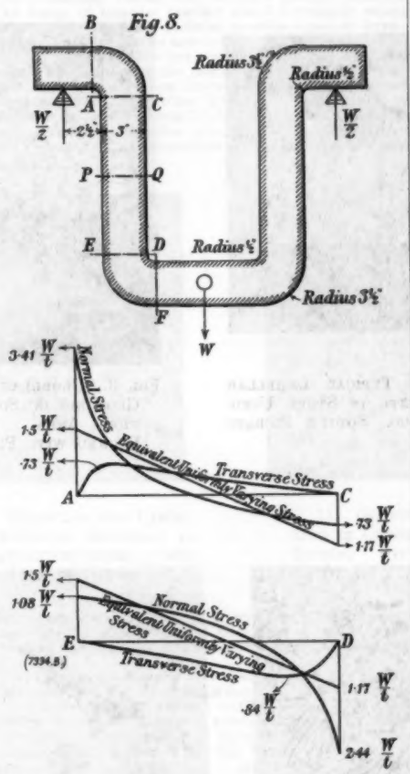
Case 6.—This relates to a curved beam bent by transverse forces T applied in the manner shown by Fig. 7. In this case the total normal force over any radial section defined by the angle θ varies as $\sin\theta$, and the total shear over the section varies as $\cos\theta$. Putting $n = 1$ and $n = -1$ in the general stress formulæ, a stress distribution can be deduced as follows :—

$$R_r = \left(A r + \frac{B}{r} - \frac{C}{r^3}\right)\sin\theta,$$

$$R_\theta = \left(3A r + \frac{B}{r} + \frac{C}{r^3}\right)\sin\theta,$$

$$S = -\left(A r + \frac{B}{r} - \frac{C}{r^3}\right)\cos\theta$$

Fig.8.



The fact that R_r and S are the same functions of r makes it possible to satisfy the condition that these two stress components should simultaneously vanish at the two boundaries $r = r_1$ and $r = r_0$. Selecting values of A, B and C in accordance with these conditions the stress distribution takes the form :—

$$R_r = P\left[-r + (r_0^2 + r_1^2)\frac{1}{r} - \frac{r_0^2 r_1^2}{r^3}\right]\sin\theta,$$

$$R_\theta = P\left[-3r + (r_0^2 + r_1^2)\frac{1}{r} + \frac{r_0^2 r_1^2}{r^3}\right]\sin\theta,$$

$$S = P\left[+r - (r_0^2 + r_1^2)\frac{1}{r} + \frac{r_0^2 r_1^2}{r^3}\right]\cos\theta$$

On integrating, the total shear stress over a radial cross-section is found to be :—

$$P t\left[(r_0^2 - r_1^2) - (r_0^2 + r_1^2)\log\frac{r_0}{r_1}\right]\cos\theta$$

and the total normal stress is :—

$$P t\left[(r_0^2 + r_1^2)\log\frac{r_0}{r_1} - (r_0^2 - r_1^2)\right]\sin\theta$$

Hence the case represented in Fig. 9 corresponds to the following stress specification :—

$$R_r = \frac{T\left[-r + \frac{r_0^2 + r_1^2}{r} - \frac{r_0^2 r_1^2}{r^3}\right]\sin\theta}{t\left[(r_0^2 + r_1^2)\log\frac{r_0}{r_1} - (r_0^2 - r_1^2)\right]},$$

$$R_\theta = \frac{T\left[-3r + \frac{r_0^2 + r_1^2}{r} + \frac{r_0^2 r_1^2}{r^3}\right]\sin\theta}{t\left[(r_0^2 + r_1^2)\log\frac{r_0}{r_1} - (r_0^2 - r_1^2)\right]},$$

$$S = \frac{T\left[+r - \frac{r_0^2 + r_1^2}{r} + \frac{r_0^2 r_1^2}{r^3}\right]\cos\theta}{t\left[(r_0^2 + r_1^2)\log\frac{r_0}{r_1} - (r_0^2 - r_1^2)\right]}$$

As R_1 decreases, the value of R_θ at the small inner radius approximates to the value $-\frac{2S}{t r_1 \log r_1}$, and consequently tends to become infinite in the case of a sharp right-angled bend. For the particular case $r_0 = 7 r_1$, the distribution of normal stress and transverse stress along the radial cross-section $\theta = \frac{\pi}{2}$ is in accordance with Fig. 7. By combining Cases 5 and 6, the stress distribution for the general case of a curved beam bent by means of concentrated transverse loads can be investigated. As an example, consider the case represented by Fig. 8 in which a stirrup cut out of a flat plate is supporting a central load W, the inner radii of the right-angled bends being ½ in. The section A B is subjected to a bending moment W combined with a shear $\frac{W}{2}$. The section D F is subjected to a bending moment 3 W combined with a shear $\frac{W}{2}$. The distributions of normal stress and transverse tension along the sections A C and D E are shown on Fig. 8. The very considerable error which would be introduced by assuming the normal stress to be uniformly distributed over the cross-sections is clearly emphasised in this calculation. This uniformly varying normal stress will, however, be approximated to in the case of the section P Q lying midway between A C and D E.

THE FORMATION OF GLOBULAR PEARLITE.*

By J. H. WHITELEY (Stockton).

IN the course of some experiments which were made during a recent investigation on pearlite† it was noticed, when small pieces about 1 gramme in weight of plain steel (carbon 0·20 per cent.), containing large grains of the eutectoid, were heated to a temperature just above Ac1 (720 deg. C.), that the whole of the cementite did not dissolve immediately in the ferrite component. While the greater part disappeared rapidly, a small residue of very fine particles always remained embedded in the γ-iron and an appreciable length of heating was necessary in order to obtain a complete solution. Specimens could be held for at least 30 minutes at 745 deg. C., before the cementite completely vanished, and even at 760 deg. C. fully 10 minutes' heating was required. A typical instance is seen in Fig. 1, which depicts part of an area of solid solution in a section of the steel which had been held at 750 deg. C. for 3 minutes and then quenched in water. After treating a polished surface with a 2 per cent. solution of picric acid in alcohol, and then with hot alkaline sodium picrate solution, the undissolved cementite particles were stained black as shown. The length of time required to effect a complete solution of the carbide was found to depend also upon the size of the pearlite grain. Thus nuclei are absent from the small areas at the top of the figure. In hypoeutectoid steels the particles dissolve more rapidly in small grains, presumably because such grains are more quickly diluted by the diffusion of ferrite inwards from the exterior.

Since areas of solid solution containing visible nuclei of cementite could thus be obtained in hypoeutectoid steel, the question arose as to what effect the presence of these nuclei would have on the character of the pearlite formed and on the position of the Ar1 point when the steel was slowly cooled down. Although a partial answer had already been given by Honda and Saito,‡ who found that the presence of carbide nuclei, more especially in hypereutectoid steels, led to the formation of globular pearlite, the question seemed worthy of further consideration on account of the work of Miers on the crystallisation of salts by inoculation in liquid solutions. It was thought that the same effects might also obtain in the crystallisation of a solid solution. Miers demonstrated that below the true solubility curve of a salt in a solution there is a "metastable" region of undercooling and consequent supersaturation, in which crystallisation can be started by inoculation, the addition of a particle of the solute or of an isomorphous substance being sufficient to bring this about. Below the metastable region there is another—the "labile" region—in which crystallisation occurs spontaneously, the initiating impulse of a germ-crystallite not being required.

Now there is good evidence to show that a considerable degree of undercooling can occur before lamellar pearlite forms from the solid solution. The variable temperature gap between the points Ac1 and Ar1 is, of itself, a proof of this, because, while the Ac1 point is fairly stationary, the Ar1 point has been found to vary widely according to the carbon content and rate of cooling. Seeing that undercooling implies supersaturation, it must also be concluded that lamellar pearlite forms from a supersaturated solid solution; and, further, the degree of lag which can occur would seem to indicate that the point of formation is, at times, not far removed from the labile region. On these grounds, therefore, it appeared of interest to ascertain whether the structure of the pearlite was modified in any way, and also whether the temperature

* Paper presented to the Iron and Steel Institute, on Friday, May 5, 1922.

† "The Formation of Pearlite in Steel," Proceedings of the Cleveland Institution of Engineers, 1921–22, No. 2.

‡ Journal of the Iron and Steel Institute, 1920, No. II, page 261.

at which the transformation began was raised to any extent by the presence of carbide nuclei in the solid solution.

For the purpose of the investigation a sample of steel plate was used, the analysis of which was as follows: Carbon, 0·20 per cent.; phosphorus, 0·06 per cent.; sulphur, 0·07 per cent.; manganese, 0·52 per cent.; silicon, 0·02 per cent. The sample exhibited the usual banded structure found in rolled material of this description. In order to obtain an even distribution of the impurities which give rise to this structure, the piece was placed at the centre of a solidifying slag ball and kept there for two days. By this means the banded structure was eliminated and large areas of well-defined lamellar pearlite obtained. An example taken from one of these areas is shown in Fig. 2.

It was, of course, essential that the positions of Ac1 and Ar1 should be known. These were found by examining microscopically small pieces of the material which had been quenched in water after they had remained for 1 hour at different temperatures in the neighbourhood of the two points. Since the degree of lag at Ar1 is known to vary according to the speed of cooling, the rates of heating and cooling which were given in these tests were approximately the same as those employed in the subsequent experiments on the effect of the presence of carbide nuclei.* Under these conditions Ac1 was found to lie somewhere between 715 deg. and 720 deg. C., for at the latter temperature the transition to γ-iron had occurred in many places, whereas at 715 deg. C. no such change had occurred. Similarly, by observing the point at which lamellar pearlite began to grow, Ar1 was found to lie between 690 deg. and 685 deg. C., when the pieces were first heated for 30 minutes at 800 deg. C.

As a preliminary experiment, a small piece of the steel, about 1 gramme in weight, was heated at 745 deg. C. for 5 minutes† and then gradually cooled to 650 deg. C. in 20 minutes. A careful examination of the pearlite thus formed showed that it was partly lamellar and partly globular, the latter type being mostly well within the areas in places where it was known that the nuclei had originally been. Since it was probable that the globular pearlite, if formed through inoculation by the nuclei and not by the balling up of newly-formed lamellæ, would grow at a higher temperature than lamellar pearlite, a second experiment was now made in which a similar piece was heated in a silica tube for 5 minutes at 745 deg. C., cooled in 2 minutes to 700 deg. C., held there for 20 minutes, and then rapidly quenched by allowing it to fall into a quantity of cold water a foot deep. On examination it was seen that the γ-iron areas had been largely transformed, the unchanged parts being at the margins where lamellar pearlite had formed in the previous experiment. In this instance hardly any lamellar pearlite was to be seen; the separated carbide in the transformed parts was almost entirely in the form of minute globules, as shown in Fig. 3. Proof that the globules were really separated carbide was obtained by immersing the section for 10 minutes in a hot solution of alkaline sodium picrate. Fig. 4 shows the same area after this treatment.*

Each particle of carbide in the globular pearlite has evidently been formed by the growth, in the γ-iron, of an undissolved particle which has acted as a nucleus upon which the carbide has been deposited. Moreover, the precipitation of carbide in this manner has occurred at a temperature about 15 deg. C. higher than that at which lamellar pearlite was found to form with the same rate of cooling in the absence of nuclei. This result was obtained when other samples of hypoeutectoid steels were similarly treated. Whenever carbide particles were present in the γ-iron, globular pearlite could be readily formed if the specimen were held at about 700 deg. C. In the illustration given the transformation has not been complete; the solid solution area at the bottom still contains undissolved particles which apparently had not started to develop before the piece was quenched. The difference in the size of the particles before and after growth can thus be compared and is seen to be very marked. It will also be noticed that, apparently, the carbide globules can remain in contact without coalescing.

The fact that the presence of particles of carbide in the solid solution causes the growth of globular pearlite in cooling has been observed, as previously remarked, by Honda and Saito, but chiefly in the case of hypereutectoid steels. Nevertheless, these authors obtained globular pearlite by heating hypereutectoid steels for 20 minutes at or just above Ac1, but they give no precise information as to the speed at which the samples were cooled. They state that: "In hypoeutectoid steels cementite is all dissolved in ferrite at the Ac1 point; hence by heating the specimens to 20 deg. or 30 deg. above the Ac1 point, the cementite in solid solution is uniformly diffused, and hence by cooling a lamellar structure is obtained."

Portevin and Bernard* have also noticed the same effect, again in hypereutectoid steels. They found that "the retardation of the solubility of the cementite above Ac1 on heating and its premature precipitation below Ac1 on cooling, are manifested by a period of intense dilatability." In a eutectoid steel, however, they failed to discover the "premature precipitation of cementite" when the pearlite was in the lamellar form prior to heating; it only occurred when the pearlite was first "coalesced" by heat treatment. In another place they state that "alterations of temperature during the passage of Ac1 provides one of the best modes of securing the coalescence of the cementite. During the periods of heating the tiny particles disappear, both because of their minute dimensions and their greater solubility, while, during the periods of cooling, the dissolved cementite precipitates on the residual particles, the dimensions of which grow accordingly."

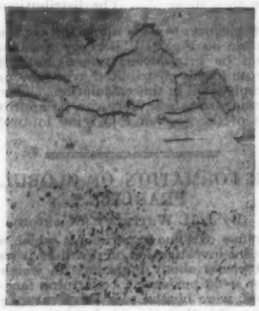


FIG. 1. PEARLITE STEEL HEATED AT 750 DEG. C. (3 MIN.), SHOWING UNDISSOLVED CEMENTITE. × 850. SODIUM PICRATE STAIN.

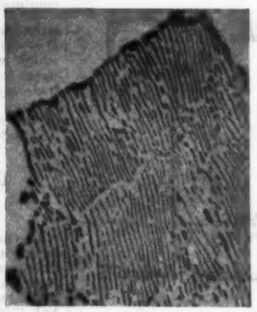


FIG. 2. TYPICAL LAMELLAR PEARLITE IN STEEL USED. × 1,500. SODIUM PICRATE STAIN.

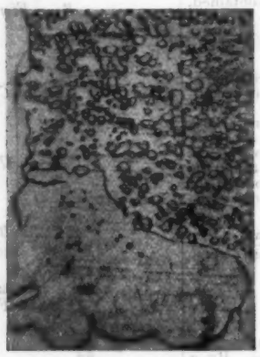


FIG. 3. GLOBULAR PEARLITE GROWING IN SOLID SOLUTION AREA. × 1,650. ETCHED WITH PICRIC ACID.

FIG. 4. SAME AS FIG. 3. SODIUM PICRATE STAIN. × 1650.

FIG. 5. LAMELLAR PEARLITE GROWING IN AREA OF SOLID SOLUTION. × 1,600. ETCHED WITH PICRIC ACID.

FIG. 6. GLOBULAR AND LAMELLAR PEARLITES. × 1,500. SODIUM PICRATE STAIN.

FIG. 7. GLOBULAR PEARLITE STARTING TO FORM. × 1,600. SODIUM PICRATE STAIN.

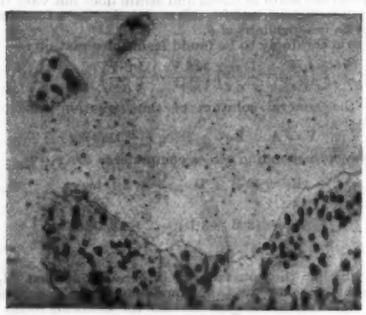


FIG. 8. GLOBULAR PEARLITE IN PROCESS OF FORMATION. × 2,250. SODIUM PICRATE STAIN.

The observations recorded in the present paper on the formation of globular pearlite through the influence of the carbide nuclei have been made chiefly when using hypoeutectoid steel. In investigating this effect a number of features were noted, some of which appeared to supplement those recorded by previous workers, and these may now be considered.

Method of finding the Point Ae.—There is evidence to show that lag occurs not only in cooling but also in heating, the Ac1 point being higher than the true equilibrium point Ae, which has been defined by Howe and Levy† as being "the temperature at which the transformation is due and would occur, were equilibrium complied with exactly." The formation of globular pearlite by growth of nuclei would appear to afford a means of ascertaining very closely the position of this point, for it is clear that as long as the steel is held at temperatures above the true equilibrium point, growth of the carbide particles will not take place. But as soon as the Ae point is passed, and the metastable region is entered, the nuclei will inoculate the solid solution and globular pearlite will begin to form.

By way of illustration, a series of experiments was made, in which specimens, about 1 gramme in weight, were heated for 3 minutes at 750 deg. C. in a small electric

*Throughout the investigation all temperature readings were taken with a Cambridge potentiometer.

†In this and all subsequent experiments, the length of heating stated does not include the time required to bring the specimen to the particular temperature used.

*A singular feature, which was repeatedly observed with both globular and lamellar pearlite, is here seen. The cementite particles have not been entirely stained by the picrate, and in each crystal of the iron the unstained parts all face the same way. This effect was not removed even after 1 hour's immersion.

*Journal of the Iron and Steel Institute, 1921, No. II, page 145.

†*Ibid.*, 1916, No. II, page 217.

resistance furnace, and then cooled at the rate of approximately 25 deg. C. per minute to various temperatures between 720 deg. and 695 deg. C., and held there for 1 hour before being quenched in water. This length of time was considered sufficient to obtain a uniform distribution of the carbon dissolved in the γ-iron areas. In the specimens heated at 720 deg. and 715 deg. C., no indication of any globular pearlite could be seen; in fact, the number of nuclei present seemed to have been reduced. Also at 710 deg. C. no globular pearlite had formed, but here no difference could be detected in the number of nuclei present when the specimen was compared with one quenched after being heated for 3 minutes at 750 deg. C. only. At 705 deg. C., however, globular pearlite had begun to appear; the area shown in Fig. 7 is typical of the degree of transformation obtained at this temperature. From these experiments, therefore, the position of the Ae point of this steel is seen to be somewhere between 705 deg. and 710 deg. C., a temperature about midway between Ar1 and Ae1.

Since it seems very probable that the formation of globular pearlite may thus be used as a means of determining the true equilibrium point with a fair degree of accuracy, it is of interest to ascertain whether the position of the point remains the same when the carbon concentration is varied; that is, whether the Ae line in the iron-carbon equilibrium diagram is horizontal. This does not appear to be the case with either the Ar or Ac line. Carpenter and Keeling, for example, show in their diagram that the Ar1 point rises about 20 deg. C. as the carbon content increases from 0·2 per cent. to 2 per cent. Dr. Stead also obtained the same result by a different method and, further, obtained evidence which indicated that the Ac1 point rises in a similar way.*

Method of Formation.—As soon as the Ae point is passed in cooling and the region of supersaturation entered, the undissolved carbide particles begin to grow by deposition of the carbide upon them from the surrounding solid solution. The steel is now at a temperature just below the triple point, and, consequently, when carbide separates, some ferrite must also separate, or the carbide concentration necessary for equilibrium conditions in the remaining solid solution will not be maintained. Minute crystals of a ferrite thus appear within the γ-iron areas at points adjacent to, or not far removed from, the carbide nuclei. For every part by weight of carbide deposited, about six parts of ferrite separate, and since this difference is not counterbalanced by the relative densities, the growing particles of carbide are eventually surrounded by the ferrite formed in the transition. An instance of the particles in process of separation from the solid solution is clearly seen in Fig. 7.

When once all the residual solid solution areas are out of contact with the carbide particles, the formation of the globular pearlite ceases and, if the temperature be not lowered, these solid solution areas will persist for long periods. With a gradual fall in temperature, however, they eventually change into ordinary lamellar pearlite. The fringe of lamellar pearlite which frequently exists at the margins of the globular pearlite areas in hypo-eutectoid steels is to be accounted for in this way. The carbide nuclei dissolve less readily at the centres of the γ-iron areas than at the margins owing, no doubt, to the fact that the carbon concentration is reduced more quickly there than further inwards. Consequently, in slow cooling, globular pearlite first forms within the areas and afterwards lamellar pearlite at the fringes. In Fig. 4 part of the untransformed border in a specimen one cooling during the time the temperature is between Ae and Ar1, but the process is not very rapid. If, therefore, fully developed globular pearlite is to be obtained in a single passage through Ar1, the metal must be cooled sufficiently slowly in order that growth may be completed before the point at which lamellar pearlite crystallises is reached; otherwise, an intermingling of the two forms will be obtained. This effect was observed in several experiments and goes to show that lamellar pearlite can grow at a faster rate than globular pearlite.

The Presence of Globular Pearlite induces Growth of Lamellar Pearlite.—The evidence appears to be conclusive that globular pearlite forms at a higher temperature than lamellar. It was noticed repeatedly, however, that the presence of globular pearlite within the γ-iron areas causes an earlier growth of lamellar pearlite at the margins than would otherwise occur during slow cooling. In this connection the following experiment is of interest. A small piece of steel was heated in a silica tube for 45 minutes at 800 deg. C., so as to dissolve all the carbide nuclei. The furnace was next cooled to 750 deg. C. and another piece was placed alongside. After this piece had been heated for 3 minutes at this temperature, the two were cooled to 690 deg. C. in 3 minutes and held there for 15 minutes. They were then rapidly quenched in water. In the first specimen neither globular nor lamellar pearlite had formed and the structure was entirely composed of ferrite and martensite. In the second specimen, both forms of pearlite were present and very little martensite; the structure was similar in every respect to those obtained previously at 690 deg. C. and illustrated in Fig. 6. Since lamellar pearlite was present in the second specimen and not in the first, it seems clear that the presence of the globular variety must have induced its

FIG. 9. GLOBULAR AND LAMELLAR PEARLITES GROWING IN THE SOLID SOLUTION. × 1,000. SODIUM PICRATE STAIN.

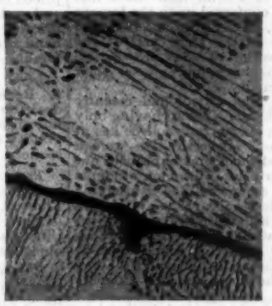


FIG. 10. GLOBULAR AND LAMELLAR PEARLITES GROWING IN HYPEREUTECTOID STEEL. × 850. SODIUM PICRATE STAIN.

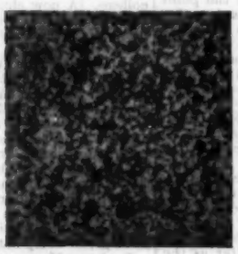


FIG. 11. GLOBULAR PEARLITE IN CHROME STEEL. ETCHED WITH PICRIC ACID. × 2,250.

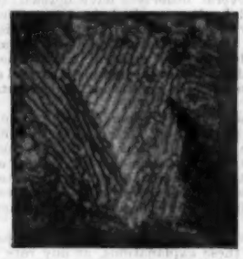


FIG. 12. LAMELLAR PEARLITE IN CHROME STEEL. ETCHED WITH PICRIC ACID. × 2,250.

As a preliminary attempt to find out the position of the Ae line, a piece of the steel previously used was case-hardened at about 1,200 deg. C. and allowed to cool down slowly during a period of 36 hours. The carbon content after this treatment was found to be in the vicinity of 1·80 per cent. just beneath the surfaces, and to diminish steadily through a distance of about $\frac{1}{4}$ in. inwards to the original amount, 0·02 per cent. In the hyper-eutectoid region, a network of free cementite was present enclosing large areas of coarse lamellar pearlite. The gradation of the carbon content thus produced by case-hardening seemed very suitable for the purpose in view, since small pieces could be obtained having a wide variation in the concentration.

Three adjoining sections were cut from the piece, and these were heated for 3 minutes at 750 deg. C. and cooled to 705 deg., 708 deg. and 712 deg. C. respectively. Each specimen was maintained for 1 hour at the particular temperature employed and then quenched in water.† At 705 deg. C. globular pearlite had formed, in small quantity, throughout. At 708 deg. C., a few small patches of globular pearlite had again formed in the hypoeutectoid area, but in the hypereutectoid it had developed rather more. At 712 deg. C. no growth had occurred in any part, and the structure now consisted entirely of martensite and ferrite.

Thus, for this steel the Ae line would appear to be straight to within 5 deg. C. At the same time, the evidence obtained rather indicated that there was a slight step upwards at the eutectoid point, and experiments with another case-hardened steel of similar composition tended to confirm this conclusion. It is possible, of course, that the presence of manganese in the steel may have a disturbing influence as the carbon content increases, owing to the formation of a little manganese carbide and consequent reduction in the amount of manganese more directly associated with the iron in the solid solution. Further work with steels free from this and other similar elements must, therefore, be done before a final conclusion on the question can be reached. Nevertheless, in the remaining sections of the paper, the lowest temperature below Ac1, at which globular pearlite will not form from nuclei in 1 hour's heating, will be referred to as the Ae point.

quenched from 700 deg. C. is seen; in a second specimen treated similarly, and then slowly cooled, these borders had changed into lamellar pearlite, as shown in Fig. 6.

It should be remarked here that, since, in the absence of nuclei, the Ar1 transformation does not occur, even with a slow rate of cooling, until the temperature has fallen well below the true solubility point Ae, direct evidence is thus obtained of supercooling, and it would almost seem as though lamellar pearlite, which is then formed, will not grow until a certain degree of supersaturation is reached.

Speed of Growth increases Rapidly as the Temperature falls below Ae.—This was repeatedly observed. For example, three specimens, equal in size, were heated separately for 5 minutes at 750 deg. C.; they were then cooled down in the furnace, at a rate of about 25 deg. C. per minute, to 700 deg., 695 deg. and 690 deg. C., respectively, and held at these temperatures for 10 minutes before being quenched. At 700 deg. C. the majority of the nuclei were embedded in the γ-iron, and only a few had developed into globular pearlite in 10 minutes. The area in Fig. 7 is typical. In another piece after 30 minutes at this temperature the change had progressed further, but even then areas of γ-iron containing undeveloped nuclei were to be seen. Fig. 8 shows part of an area of γ-iron in the specimen quenched from 695 deg. C.; the transformation was far more advanced, yet it was by no means complete, as can be judged from the large number of nuclei present in the solid solution area. At 690 deg. C., however, 10 minutes was almost sufficient to effect a complete transformation. Only small isolated areas not containing visible nuclei were present, and the structure was similar in every way to that of Fig. 6. The presence of lamellar pearlite in this specimen will be discussed in the next section.

It is thus clear that, as the temperature falls below Ae, there is a marked acceleration in the rate of growth of globular pearlite. That the process will quicken to some extent with a falling temperature is, no doubt, to be expected, since the diffusion gradients must get steeper owing to the γ-iron becoming increasingly supersaturated; but it is by no means certain whether the rapid increase in the rate of growth can be entirely explained in this way because, although the gradients steepen, the diffusion constant probably diminished.

As before mentioned, Portevin and Bernard recommend alternations of temperature during the passage of Ac1 for securing globular pearlite. The foregoing experiments show that this type of pearlite may be formed in earlier growth. A similar instance was also seen in the previous section.

Further evidence of this induced growth is to be found in the different manner in which the two pearlites form. The globular always starts to form within the γ-iron areas by growth of the undissolved carbide nuclei. On the other hand, as far as the author's observations extend, in the absence of globular pearlite, lamellar pearlite begins to form at the margins of these areas. An instance is given in Fig. 5. It shows this type of pearlite in process of formation in a specimen quenched at Ar1. Growth had clearly started at the margin of the area and the crystallisation of the lamellæ was proceeding inwards when the specimen was quenched. When lamellar pearlite is induced to form by the presence of globular pearlite, however, growth occurs in the reverse direction. The lamellæ start at a point adjacent to the transformed part within the solid solution area and then travel outwards. An example is seen in Fig. 9, which is typical of the effect obtained when a specimen was heated for 3 minutes at 750 deg. C., cooled in 10 minutes to 687 deg. C., and then quenched before the pearlite had developed completely. The lamellæ were clearly travelling outwards to the margins at the time of quenching, growth having evidently been induced by the previously formed globular pearlite.

Formation of Globular Pearlite in Hypereutectoid Steels.—As the carbon content is increased above the eutectoid amount, the temperature above Ac1 at which the whole of the carbide completely dissolves in the γ-iron rapidly rises as indicated by the cementite solubility curve in the equilibrium diagram. Consequently the interval in which carbide nuclei can remain undissolved will widen, since saturation of the γ-iron can be maintained by the solution of the pro-eutectoid cementite as well as the eutectoid. Although this is undoubtedly the case, experiments which have been made during the present investigation have not always been successful in producing globular pearlite free from lamellar pearlite in hypereutectoid steel, containing carbide nuclei, by holding it at a temperature not far below Ae. With some steels there was no difficulty, but with others an intermingling of the two varieties was invariably obtained.

This effect was especially observed in the case-hardened material referred to above. For example, when a piece was cooled from 750 deg. to 690 deg. C. in 30 minutes, the hypereutectoid region was almost entirely composed of lamellar pearlite, whereas in the eutectoid and hypoeutectoid areas well-defined globular

* Proceedings of the North-East Coast Institution of Engineers and Shipbuilders, 1912–13, vol. xxix.

† Frequent readings were taken on the potentiometer during the heatings, and in each case the temperature was shown not to vary more than ±1 deg. C. from that stated.

pearlite had formed. Again, in the experiments on the position of the Ae line made with this steel, in which sections were held for an hour just below Ae, some lamellar as well as globular pearlite was always to be seen. An example of the pearlitic structure obtained at 705 deg. C. is shown in Fig. 10. This difficulty has apparently not been encountered by the authors previously quoted. It may be that lamellar pearlite is induced to form in the presence of globular pearlite more readily in hypereutectoid steels because the temperature interval between Ae and Ar is lessened; but the reason why this should occur in one case and not in another has yet to be found.

Formation of Globular Pearlite a Test for the Presence of Carbide Nuclei in the γ-Iron.—From observations made during the investigation, it was concluded that the carbide particles can be ultra-microscopic in size and yet cause globular pearlite to grow when the steel is held a few degrees below Ae. Visible and relatively coarse particles do not appear to be essential. To verify this conclusion, two pieces of the steel were heated for 15 minutes at 760 deg. C. and one piece was then quenched; the other was also quenched after it had been cooled to 700 deg. C. and held there for 1 hour. On examination well-defined globular pearlite was found to have grown at the centres of the γ-iron areas in the latter specimen. In the piece quenched from 760 deg. C., however, the presence of carbide nuclei could not be detected with certainty under the highest magnification available. Nevertheless, the growth of the globular pearlite at 700 deg. C. clearly indicated that they were still present in the central portions of the solid solution areas. The experiment was repeated several times and in each instance the same result was obtained.

The persistence of carbide nuclei in the γ-iron at high temperatures has more than once been suggested as the reason why the temperature of the Ar1 transformation can vary according to the heat treatment given. Several observers have noticed that the point is lowered by long or high heating. The explanation offered by Howe and Levy of this fact is as follows:* "Raising the temperature above Ac1 tends to impair and to destroy the existing transformation starting nuclei, and the higher the heating is carried and the longer it is maintained, the greater is this destruction or impairment."

Dr. Rosenhain had apparently the same idea in mind when he stated that "the higher the temperature to which the steel had been raised, the more completely would the carbide particles be destroyed and the fewer would be the nuclei remaining when the steel came to be cooled down. Thus there might be different degrees of undercooling (at Ar1) according to the temperature to which the steel had been heated."†

The evidence advanced in the present paper is not in favour of these explanations, at any rate as far as the eutectoid and hypoeutectoid steels are concerned. With these steels comparatively short heatings at temperatures above 800 deg. C. sufficed to prevent the formation of any globular pearlite when the samples were held for an hour 10 deg. C. below the Ae point. Moreover, on further cooling, lamellar pearlite was formed and, as previously remarked, growth then starts at the margins of the γ-iron areas. Growth in this manner would scarcely happen if it had been induced by the presence of nuclei within the areas. Consequently, it seems legitimate to conclude that by heating the specimens to above 800 deg. C., a complete solution of the carbide had been obtained and that no undissolved nuclei remained. It would seem, therefore, that the effect on the position of Ar1, brought about by heating to higher temperatures still, must be assigned to some other cause.

It is well known that with certain special steels, "T max" exerts a similar, but much more pronounced, influence upon the position of Ar1. This is especially the case with steels containing chromium. Recently Monypenny, in an instructive paper,‡ has shown that in such steels there is a very considerable range of temperature above Ac1 in which particles of undissolved carbide persist for long periods of heating. He further states that, in cooling, the presence of these particles causes globular instead of lamellar pearlite to form.

These results were fully corroborated during the present investigation with a steel containing 3·78 per cent. of chromium and 0·58 per cent. of carbon. It was seen that even after 20 hours at 800 deg. to 850 deg. C., undissolved particles of carbide still remained in the solid solution, and in cooling slowly globular pearlite was formed. Heating the steel between 900 deg. and 950 deg. C. for 1 hour, however, caused the particles to disappear completely, and in these cases lamellar pearlite was formed when the specimen was cooled at a similar rate. Illustrations of the two pearlitic structures obtained are given in Figs. 11 and 12. Further work showed that, as with plain carbon steels, the globular pearlite grew at a temperature about 20 deg. C. higher than lamellar pearlite. Owing to the greater range of temperature above Ac1 permissible, also to the length of time the nuclei persisted in this range, and again to the slow rate at which lamellar pearlite grew in this steel, it was easy to produce specimens in which the pearlite was entirely globular. Here also, therefore, the formation of lamellar pearlite would indicate the absence of carbide nuclei from the solid solution. It thus again seems clear that some other explanation must be sought of the progressive lowering of Ar1 which occurs as "T max" is raised above the minimum temperature of heating required to cause the growth of lamellar pearlite alone in the subsequent cooling.

* *Loc cit.*, page 218.

† Discussion of Stead's paper referred to above.

‡ Journal of the Iron and Steel Institute, 1920, No. 1, page 493.

THE ENGINEERING PROFESSION IN SCANDINAVIA.

On relinquishing his directorship of the large polytechnic college in Copenhagen, a post he had filled with distinction for ten years, Professor H. I. Hannover, in his farewell address, delivered before a large and distinguished audience, including the King of Denmark, gave interesting particulars concerning the study of engineering in Denmark and referred also to Sweden and Norway.

The number of students entering the college last year was 222, the 22 having been specially provided for, a number exceeding that of any of the professions at the Copenhagen University. The Copenhagen polytechnic college was able to receive all applicants (the announcement made at first to the effect that only 200 could be received may have acted as a deterrent), whilst Sweden's technical high school could only receive 199 students out of 259 applicants, and Norway's technical high school only 122 out of 177 applicants.

Professor Hannover said most of the students worked hard and satisfactorily. Thus one student, 19 years old, in the second term of his study, earned the gold medal of the Danish Society of Science. Some of the students had to contend against pecuniary difficulties; one cheerfully did harvest work in the summer vacation and another, who passed the final examination with first-class honours, put in a couple of months as a workman in Messrs. Burmeister and Wain's works.

A Government grant has been voted for a mechanical technological laboratory, and there were now funds for three laboratories; the difficulties of finding a suitable site would, he hoped, soon be overcome.

The first technical degree of Doctor *hon. causa* had in the course of the year been conferred upon the famous French scientist in chemistry, Henry Le Chatelier, who had delivered three lectures in the large hall of the college. A new chair had been established in technical hydraulics, and the first engineers had passed their final examination in this speciality.

Whilst Sweden's technical high school had recently had its first regular female student, Norway having only two such students, the Danish polytechnic college has at present 34 women students. Hitherto the women students had generally selected the chemical branch, but at present, besides 25 of this class, 7 women students are studying to become civil engineers, one is studying machinery and another electricity. The latter, a countess, is very enthusiastic in her studies and has just started on a four months' training course on board the Selandia, bound for the Far East, for which trip she had to be taken as a common sailor, although having her own private cabin. On the whole, the lady students have given every satisfaction.

Professor Hannover gave a short survey of the development of the college during his ten years' tenure of office. During that period the number of students had risen from 723 to 1,024 (exclusive of some 150 who were at present completing their workshop training or for other reasons had interrupted their studies). The number of members on the teachers' council had risen from 39 to 48 and that of assistants from 28 to 51. In 1912, 101 students passed their final examinations, in 1922 there will be about 160. The capital for scholarships had increased from 39,200 kroner to over 600,000 kroner. This latter sum is not large considering the number of students. At the Stockholm technical high school the capital for scholarships was twice as large.

In conclusion, Professor Hannover handed the director's insignia to his successor, Professor P. O. Pedersen, who had been one of his most capable pupils, and who had carried out a large amount of scientific work.

COBALT.—The chief sources of cobalt ores are the mines of Cobalt (Ontario) and of Cloncurry in Queensland. In the former mines cobalt is associated both with nickel, which it generally accompanies, and with silver; in the latter nickel is almost absent. Physically cobalt and nickel are very similar to one another: atomic weights Co 58·97, Ni 58·7, density of both 8·8, atomic volume 6·9 and 6·7, melting-points 1,478 deg. and 1,452 deg. C. Chemically both the metals give a perplexing variety of compounds of peculiar colours; but there the resemblance almost ends. Metallurgically the two metals are very different. An addition of 15 per cent. of nickel to copper makes the copper white and like nickel; a copper containing 30 per cent. of cobalt, however, is still like copper. The nickel alloys represent one solid solution throughout the range; the Co-Cu alloys are complex and give at least four series of solid solutions. Both the tensile strength and the compressive strength of cobalt (99·7 per cent.) are very high for pure metals, viz., 15·35 and 54·5 tons per square inch. The "stellite" alloys of cobalt with chromium are much-valued materials for high-speed tools; these alloys may also contain tungsten and molybdenum. Cobalt-iron alloys were first made ten years ago, in Becker electric furnaces; their exceptionally high value as magnet steels was mentioned in a paper on magnetos brought by E. A. Watson before the Institution of Electrical Engineers a year ago. When Kaimus began to study the possibilities of cobalt in Canada before the outbreak of the war, much hope was placed on the development of the cobalt electroplating industry. Those expectations, W. R. Barclay points out in the Journal of the Society of Chemical Industry, of April 29, have not been fulfilled. The costs of the process, especially of the preparation of the materials, remain high, and it may be said in general that cobalt has still to make its place in industry. The peculiar difference between nickel and cobalt seem to invite special study by X-rays and other modern methods; very little has been done in that respect, so far as we are aware.

CATALOGUES.

Feed Water.—A catalogue with clear text and illustrations relating to evaporators for supplying distilled feed water for boilers, is to hand from the Griscom-Russell Company, 90, West-street, New York.

CO_2 Recorder.—The Uehling Instrument Company, Paterson, New Jersey, U.S.A., send a clearly written and illustrated catalogue of their CO_2 recording equipment for boiler installations.

Motor Accessories.—A catalogue dealing with oil storage tanks, oiling cans and fillers, and also including some neat metal fittings, is to hand from Messrs. Joseph Kaye and Sons, Limited, 93, High Holborn, London, W.C. 1.

Electric Fuses.—The Westinghouse Electric Company, East Pittsburg, U.S.A., send a neat little pamphlet explaining the construction and use of their fuses for protecting circuits carrying up to 600 amperes. The fuses are made with either blade or ferrule contacts.

Wood Working Machinery.—A considerable range of wood-working machines with the necessary saws, cutter blocks, bits and other edge tools comes from Messrs. Watts Brothers, Limited, Keeton's Hill, Sheffield. Tables of sizes and prices of the tools are given.

Asbestos Roofing.—A catalogue of corrugated roofing sheets made of asbestos cement is to hand from the Eternit Pietra Artificiale Company, of Italy, whose London office is at Norfolk House, Laurence Pountney Hill, E.C. 4. Ridge sheets to fit the same corrugations are also supplied.

Drawing Office Requisites.—A very comprehensive priced catalogue of mathematical, surveying, draughting and other instruments, and papers, cloths, photo-printing apparatus and general office equipment is to hand from Messrs. A. West and Partners, 36, Broadway, London, S.W. 1.

Light Alloy.—Messrs. F. A. Hughes and Co., Limited, 3, Regent-street, London, S.W. 1, send catalogues describing the uses and working of a white metal alloy known as "Electron" which is about half the specific gravity of aluminium. It is supplied in ingots, castings, sections, sheets, stampings and all usual forms.

Transformers.—The eighth number of the pamphlets on transformers issued by Messrs. Johnson and Phillips Limited, Charlton, London, S.E. 7, explains the character of third harmonic voltages and currents in symmetrical three-phase systems and the particular effects which are objectionable.

Electric Driving of Machine Tools.—Matter previously issued on the subject of electric motor drives for machine tools, with much additional material, has been combined in a new and comprehensive catalogue of 40 quarto pages issued by the Metropolitan Vickers Company, Limited, Trafford Park, Manchester.

Street Lighting.—An illustrated catalogue of 36 quarto pages, issued by the General Electric Company, Limited, Kingsway, London, W.C. 2, seems to contain all that is necessary for electric street lighting. Fittings of all kinds are dealt with; clear particulars are given of the technical and financial aspects. The light is produced by gas-filled lamps which are supplied in a range of lighting powers from 30 watts to 1,500 watts per lamp.

Steam Engines.—A leaf catalogue of a steam engine for factories requiring both power and heating steam is to hand from Messrs. Galloways, Limited, Manchester. It is a tandem compound engine, with low-pressure cylinder of the uniflow type, and the heating steam is taken from the intermediate receiver. The engine is designed to maintain a constant speed and to give a steady pressure of heating steam under a varying load.

Ejector Air Pumps.—The central condenser type of multi-ejector air pump made by the Mirlees Watson Company, Limited, Scotland-street, Glasgow, is described and illustrated in a special catalogue which engineers in charge of large condensers will find worthy of study. The certain rejection of air from the boiler feed and the maximum transfer of heat from the condensing process to the additional feed water are features of the system, though the simplicity of operation and certainly of action are the main advantages.

Grain Handling Plant.—A description of the grain conveying and storage plant installed at the port of Dublin is given in a pamphlet issued by Messrs. Henry Simon, Limited, 29, Mount-street, Manchester. The total storage capacity is 13,800 tons, and the conveying machinery is in three sets, each of which has a capacity of 40 tons per hour. The grain is taken from the ships by suction and discharged to barges or otherwise by pressure, the same pipes being used for either process. In this plant the stores are 100 yards from the quay and the pipes pass underground leaving the surface clear. The illustrations in the pamphlet are clear and the text is very complete.

Ingot Lifting Machines.—"Handling machines" for ingots are travelling cranes with gear which lifts, lowers and conveys hot or cold steel ingots. The machines are operated by a man travelling in a cab attached to the crane and tolerably clear of the heat. The Wellman-Smith-Owen Engineering Corporation, Limited, Darlaston (36, Kingsway, London, W.C. 2), send us a catalogue of these machines giving 30 or more large photographic illustrations of machines in operation in order to show their adaptability to the work. Some idea of the atmospheric conditions encountered and of the importance of secure, rapid and accurate handling of the loads is necessary for the full appreciation of the catalogue.

"ENGINEERING" ILLUSTRATED PATENT RECORD.

SELECTED ABSTRACTS OF RECENT PUBLISHED SPECIFICATIONS UNDER THE ACTS OF 1907 AND 1919.

The number of views given in the Specification Drawings is stated in each case; where none is mentioned the Specification is not illustrated.

Where inventions are communicated from abroad, the Names, &c., of the communicators are given in italics.

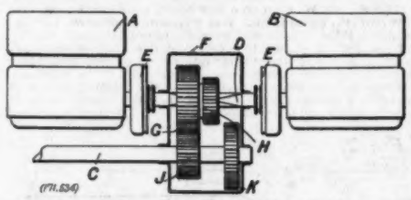
Copies of Specifications may be obtained at the Patent Office, Sales Branch, 25, Southampton Buildings, Chancery-lane, W.C., at the uniform price of 1s.

The date of the advertisement of the acceptance of a Complete Specification is, in each case, given after the abstract, unless the Patent has been sealed, when the word "Sealed" is appended.

Any person may, at any time within two months from the date of the advertisement of the acceptance of a Complete Specification, give notice at the Patent Office of opposition to the grant of a Patent on any of the grounds mentioned in the Acts.

AERONAUTICS.

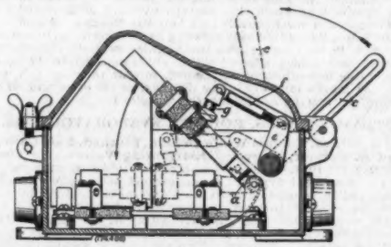
171,534. Sunbeam Motor Car Company, Limited, Wolverhampton, and L. Coatalen, Wolverhampton. Transmission Gearing. (1 *Fig.*) September 6, 1920.—This invention relates to transmission gearing for use on aircraft of the kind in which a driven shaft carrying or connected to the propeller or propellers is driven through the medium of a change-speed gear by a driving shaft operatively connected with two or more engines. According to this invention, the driving shaft is situated between two engines in alignment with their respective crankshafts and is adapted to be clutched directly to either or to both. The drawing shows diagrammatically a construction in which two engines A and B drive a single driven shaft C which carries or is



coupled to a propeller or propellers. Each engine is connected with the driving shaft D through a friction clutch E, and the driving shaft passes through a gear-box F wherein it carries a pair of sliding gears G and H. This sliding gear G, H is adapted to be meshed with either of the gear wheels J and K on the driven shaft. When both engines A and B are in use and are functioning normally, the larger gear ratio G, J would be used, but should it be desirable to stop either engine the gear G, H is moved to the right so that the wheel H meshes with the wheel K and the single engine drives the propeller at a slower speed, but the engine runs at its efficient high speed. To disconnect either engine its friction clutch is, of course, withdrawn. (*Sealed.*)

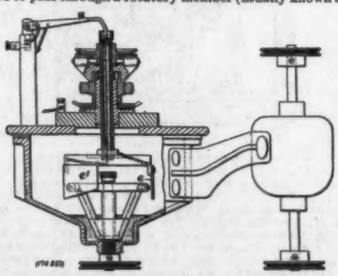
ELECTRICAL APPARATUS.

174,406. The Cable Accessories Company, Limited, Tipton, F. H. Reeves, Tipton, and A. Crawford, Tipton. Electric Switches. (1 *Fig.*) October 14, 1920.—This invention relates to an electric switch of the type having a pivoted operating member *c* furnished with an arm *e* which is coupled by a first link *f* to a second link *g*, and which second link is adapted to actuate the contact member *a* and still to be



capable of a degree of angular movement in relation thereto in order to provide for a quick break action under the influence of a spring. The invention comprises a switch of this type, in which the second link *g* is pivotally connected to the contact member *a* at a point removed from the axis of the latter, so that both axes of the second link move in the operations of closing and opening the switch. (*Sealed.*)

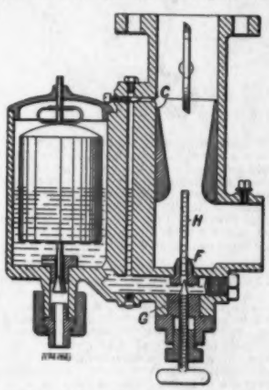
174,523. M. A. Codd, London. Induction Coils. (1 *Fig.*) January 20, 1921.—This invention relates to mercury make and break devices for induction coils of the kind in which the mercury is caused to pass through a rotatory member (usually known as the



"jet" and hereinafter so referred to), from which it is impelled on to the contacts. According to the present invention, a mercury make and break device of the kind referred to is provided with contacts *c*, *c*1 on which the mercury impinges, which are adapted to be rotated in a direction opposite to that of the rotation of the jet, through or by which the mercury is impelled on to the contacts. With the ordinary stationary contacts, the frequency of the interruptions is increased by increasing the speed of rotation of the jet, but owing to the difficulty of maintaining a satisfactory pumping of the mercury at very high speeds of rotation of the jet, the speed of rotation can only be increased up to the point at which the pumping of the mercury is not interfered with. Beyond this point the device ceases to function satisfactorily owing to irregularities that are set up in the pumping action so that it has not been feasible further to increase the frequency of the interruptions beyond a certain limiting speed of rotation of the jet at which uniform and steady pumping of the mercury ceases. By means of the present invention these disadvantages are overcome, and greatly increased frequencies of interruption are obtained. (*Sealed.*)

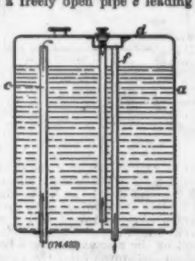
GAS ENGINES, PRODUCERS, HOLDERS, &c.

174,166. C. Binks (1920), Limited, Eccles, C. Binks, Eccles, H. Binks, Eccles, and C. L. Binks, Eccles. Carburettors. (1 *Fig.*) October 16, 1920.—This invention relates to carburettors for internal-combustion engines provided with a pilot or auxiliary jet for slow running. According to this invention, to a carburettor provided with a pilot or auxiliary jet C



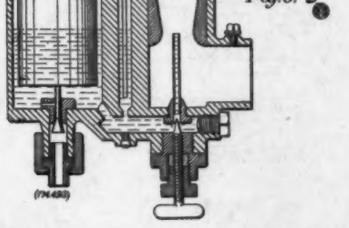
and a main supply jet F constructed of a small open-ended tube without a restricted orifice, an adjustable needle valve G is fitted at the base or foot of the main jet F to restrict the fuel supply to the jet, thereby constituting the jet a reservoir H to hold a small reserve of petrol when running slow, to give a richer mixture for use when starting or accelerating the motor. (*Sealed.*)

174,423. J. A. Peters, Scarborough. Internal-Combustion Engines. (1 *Fig.*) October 21, 1920.—This invention relates to means for supplying lubricant to internal combustion engines of the kind operated by the pressure of the exhaust gases exerted through a freely open pipe *e* leading into the oil con-



tainer *a* above the level of the oil therein. Now, according to this invention, a vented passage or reservoir *d* is provided between the oil container *a* and the gravity-fall pipe *f*, so that when the engine stops, the supply of oil will also be arrested and will not be liable in certain circumstances to continue owing to the siphoning action of the gravity-fall pipe. (*Sealed.*)

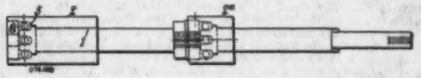
174,493. C. Binks (1920), Limited, Eccles, C. Binks, Eccles, H. Binks, Eccles, and C. L. Binks, Eccles. Carburettors. (3 *Figs.*) July 2, 1921.—This invention relates to carburettors for internal-combustion engines fitted with an auxiliary pilot jet *a*, the latter being provided with a delivery



valve D and hand lever E by which the valve can be readily turned full open to give an increased supply of fuel for starting the engine and readily turned in the reverse direction to reduce the supply of fuel when the engine is running. The invention consists in the application to or combination with the pilot jet *a* of a carburettor, of a plug valve D formed with a scroll or tapering duct around its exterior, and a hand lever fitted thereto to rotate it, by which the supply of petrol through the jet can be easily and readily adjusted to increase the supply when starting the engine. (*Sealed.*)

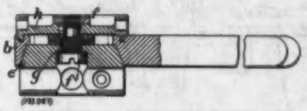
MACHINE AND OTHER TOOLS, SHAFTING, &c.

174,139. F. Pearson, Liversedge. Tool Holder. (5 *Figs.*) October 8, 1920.—This invention relates to a holder for boring and tapping tools and the like. According to this invention, one part of the tool holder comprises a rod 1 loosely mounted in a shell 2 and prevented from turning therein by a number of balls 6 capable of longitudinal movement in co-axially arranged passages



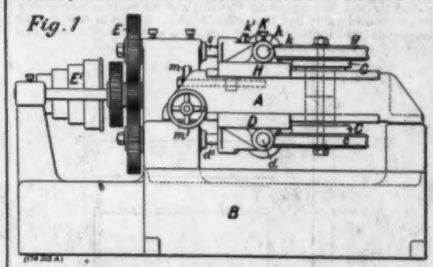
5 in the shell 2 and rod 1, and the other part, that is the portion situated on the right-hand side of the drawing and which carries the reamer, is loosely mounted in a shell 2a that is attached to the first part, rotation of the second part in relation to the shell being prevented by a similar arrangement of balls and passages. (*Sealed.*)

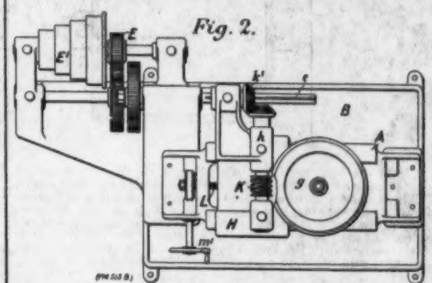
173,967. Staines Motor Company, Limited, Staines, and H. H. Clark, Staines. Turret Tool Holders. (3 *Figs.*) December 23, 1920.—This invention relates to turret tool-holders of the type comprising a shank designed to be clamped to the lathe slide-rest in the usual way and the outer end of which carries a circular socket in which is revolubly mounted a circular tool-holder having radial sockets or holes for the reception of the several tools which are secured therein by any suitable means, such as clamping screws, the tool-holder being formed conical to fit a conical seating in the socket. According to this invention, a central bolt *f* in the tool-holder is provided with a screw thread *g*

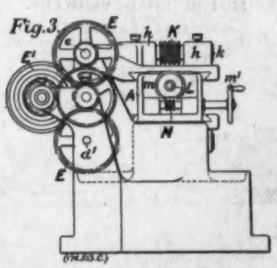


which engages a corresponding female thread in the tool-holder *c*, and is provided with means *h* for turning the bolt which, when turned in one direction, will, by screwing into the holder *c*, draw the latter so that its conical surface frictionally engages the corresponding surface of the socket *b*. The reverse movement of the bolt releases or separates the said surfaces. The end of the bolt which screws into the holder *c* is provided with a head *f*1 to limit the movement of the bolt when releasing the holder from the socket and which, by contact with the tool-holder, serves positively to rotate the latter by a continuation of the reverse movement of the bolt. (*Accepted January* 25, 1922.)

174,513. F. Matthews, Fallowfield, Manchester. Cutting Worm Wheels. (3 *Figs.*) December 22, 1920.—This invention relates to worm wheel copying apparatus in which worm wheels are cut by a hob cutter. The bed A of the machine is constructed





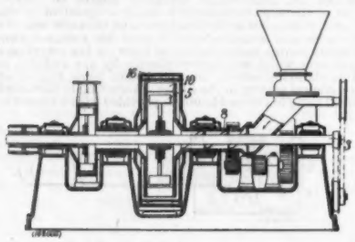


with two horizontal faces and is supported at one or both ends upon a frame B and rigidly affixed thereto. On the under horizontal face of the bed a rotary carrier C is mounted to carry a pattern or template *c* of the wheel to be cut, and an adjustable slide D with bearings for a shaft *d* of a worm gearing with the

teeth of the template wheel *e*. The worm shaft *d* and worm are driven from the main gearing E through a shaft d^1 by bevel gearing similar to the gearing k^1 shown in Fig. 2, for driving the cutting hob K. The slide D is rigidly affixed to its bed by bolts when the machine is at work, but can, by loosening the bolts, be adjusted to templates of different sizes. On the upper horizontal face of the bed A a rotary carrier G, corresponding with the carrier C, is mounted to carry the work or blank wheel *g* to be cut. The carrier G is connected with the carrier C and is rotated by the latter so that the work or blank G rotates at the same speed as the template *e*. An adjustable slide H is mounted on the upper face of the bed A, and this carries in the bearings *h* the shaft of a hob cutter K, by which the blank wheel *g* is cut. The shaft *k* and cutter K are driven by bevel gearing k^1 from the main gearing E. The shaft *e* is capable of sliding through the bevel wheel on it as the cutter K is fed to the work. The slide H and cutter K are moved to and from the work *g* by a screw L, by a worm M and worm wheel *m* and hand wheel m^1. The machine is driven by a belt on the cone pulley E^1 through the gearing E, and the bevel wheels on the shafts d^1, *d*, *e* and *k*. (*Sealed.*)

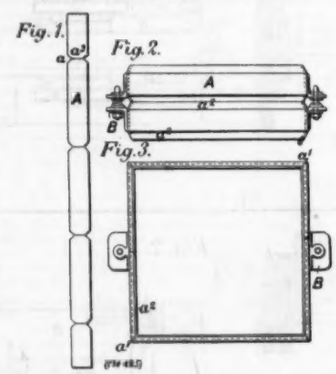
MINING, METALLURGY AND METAL-WORKING.

168,033. The Powdered Fuel Plant Company, Limited, Westminster (*the Assignees of Société la Combustion Rationelle, Paris, France*). **Pulverising Coal.** (2 *Figs.*) August 17, 1920.—This invention has relation to pulverising apparatus of the kind in which the coal during its passage therethrough is subjected to a hammering action by sets of impactors which are mounted on separate shafts, are disposed co-axially and are driven in opposite



directions at a high speed. A pulveriser of the kind referred to, in accordance with this invention, comprises the combination with co-axially disposed sets of impactors 10, 5 mounted on separate and co-axial shafts 8, 3, respectively, driven in opposite directions and a casing 16 within which the impactors are contained, of a channel constituted by the shaft 8 carrying the impactors 10 for the passage of coal to and from the centre of the casing 16. (*Sealed.*)

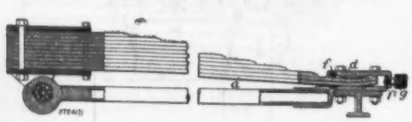
174,495. A. P. Leigh, Salford. Foundry Moulding Boxes. (11 *Figs.*) November 25, 1920.—This invention relates to moulding boxes for use in foundries. The box is formed from a single strip of sheet or plate metal A, with V-shaped notches or recesses *a* formed at intervals along its edges opposite to which the corners of the box will come. The metal strip A is bent along the top and/or bottom edges to a degree considerably less than right angles, and again bent on the lines a^b at right angles for rectangular boxes, opposite the notches *a*



to form the box, until the two edges of the V notches are in contact, the edges being then welded together at a^1, thus forming inclined flanges a^2 around the inner edges of the box, turned in to a considerably less degree than a right angle. The two ends of the metal strip A are arranged to abut along one of the sides, and may be welded together. One of the box fittings B may be riveted to the box at both sides of the junction of the two ends, thus strengthening the box. (*Sealed.*)

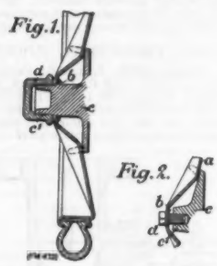
MOTOR ROAD VEHICLES.

172,417. Carrow Cars, Limited, Hanwell, London, H. Maryon, Hanwell, London, and L. Wood, Hanwell, London. Vehicle Springs. (2 *Figs.*) September 7, 1920.—The invention involves a structure in which the ends of the springs which bear upon the axle work loosely in lubricant-containing boxes closed at the outer ends and mounted on or adjacent



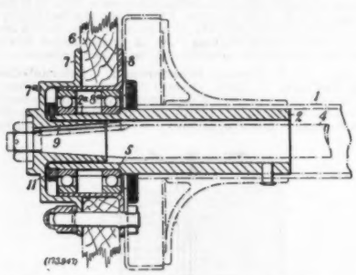
the ends of the axle in such a manner that the spring ends are free to slide backwards and forwards in the boxes in the longitudinal direction of the vehicle. According to this invention, the inner and outer ends of the boxes *d* are closed to retain the lubricant and to render the boxes weather and dirtproof by means of pads of felt *f*, f^1. The boxes *d* and the parts of the springs *a* therein are lubricated by the provision of grease or oil cups *g*, or, in certain cases, may be lubricated by forming a duct leading to the interior of the axle casing and allowing the lubricant to work along said duct into the boxes. (*Sealed.*)

174,473. O. D. North, Chelsea, London. Disc Wheels. (4 *Figs.*) November 9, 1920.—The invention relates to vehicle disc wheels. The disc constituting the body of the wheel is retained in position on the wheel hub solely by means of one or more fastening devices detachably engaged with the outer end of the hub, the central portion of the disc being thus clamped between the fastening device or devices and the radially-extending hub flange. The disc *a*, which constitutes the body of the vehicle wheel and is of conical form, may be formed with a central aperture



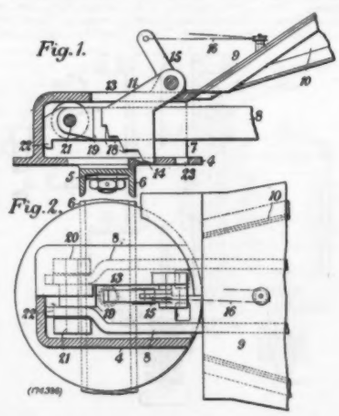
b, and be retained in position on the hub *c* by means of a single nut or stud *d* which is adapted to engage co-operatively with a correspondingly threaded part c^1 on the outer end of the hub. No fastenings, beyond this single nut or stud, are necessary, and the ring of bolts or studs, hitherto used, is unnecessary. In Fig. 1 the inner periphery of the disc body *a* surrounds the hub *c*, but in Fig. 2 the disc is extended towards its centre in a manner to overlie the end of the wheel hub so as to serve as a cap, the central aperture being comparatively small. (*Sealed.*)

173,947. J. Mitchell, Liverpool. Axles. (2 *Figs.*) November 25, 1920.—This invention relates to the axles of motor road vehicles. According to this invention, the axle drives the wheel by means of a cap plate socketed and keyed on the axle end and bolted to the hub of the wheel and a retaining ring, independent of the fastening of the wheel to the axle, is fitted on the extreme end of the sleeve which engages the ball race or an element on the wheel. In carrying out the invention, the axle tube 1 is provided with a stout sleeve-like extension 2. The bore of the sleeve 2 is of larger diameter than the axle 4, and on the exterior of the sleeve are fitted the ball bearings 5. The



hub 6 of the wheel is carried between outer and inner cheek plates 7, 8, the inner plate 8 having a tubular extension 8*a*, between which and the end 2*a* of the sleeve the ball races are disposed. The outer plate 7 is continued to form a cap 7*a*, the eye portion 9 of which is formed as a socket coned to fit the coned end of the axle 4 and keyed thereon. Consequently the hub 6 is driven direct by the rear axle 4, the wheel hub 6 being, however, journalled on ball races 5 on the exterior of the end 2*a* of the sleeve 2. A retaining ring 11 screws on the extreme end of the sleeve extension 2*a*, this retaining ring 11 engaging the outer ball race. (*Sealed.*)

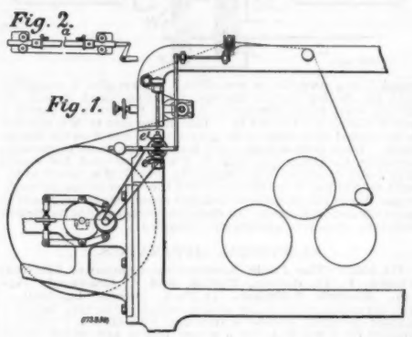
174,386. W. J. Hollick, Manchester. Automatic Couplings. (4 *Figs.*) July 15, 1920.—This invention relates to automatic couplings for vehicles, more particularly road vehicles. According to this invention, one member of the coupling, conveniently the draw-bar of a two-wheeled trailing



vehicle, is provided with a part which, in the event of uncoupling being attempted with the trailing vehicle so loaded as to be wrongly balanced, engages a complementary part on the other member of the coupling, and thereby prevents separation of the coupling members and uncoupling of the vehicles. The coupling comprises a box 4 mounted on a vertical pivot 5 on the frame member 6 of the tractor vehicle and provided with an aperture 7 for the entrance of the forward end of the draw-bar 8 of the two-wheeled trailing vehicle. For guiding the end of the draw-bar 8 to and through the aperture 7, there is fitted in conjunction with the latter and mounted on a suitable part of the tractor vehicle, so that it does not pivot with the block 4, a rearwardly and upwardly extending jaw 9 provided with edge flanges 10. The box 4 is provided with a more or less sector-shaped pivoted catch 11, operating when raised through a slot 13 in the upper wall of the box and engaging when in the normal position, as illustrated, in a recess 14 in the bottom wall of the box. The catch 11 is provided with a tail piece 15 to which is attached a cord 16, on the pulling of which the catch is raised on its pivot. The forward face of the catch is preferably formed with a series of steps 18. The draw-bar 8 is bifurcated, and the forward ends of the bifurcations have fitted between them a distance-piece 19. When the two-wheeled trailing vehicle is uncoupled, it tips backwards and rests upon a rear leg or legs with the forward end of its draw-bar 8 raised. On the tractor vehicle being backed towards the trailing vehicle, the rollers 20 on the draw-bar 8 engage the jaw 9. As the tractor vehicle continues to back, the rollers ride down the jaw, and the front end of the draw-bar passes through the aperture 7 into the box 4, raising the catch 11, which subsequently falls behind the distance-piece 19, and thus couples the draw-bar. To uncouple the vehicle, the catch 11 is raised by pulling on the cord 16, the trailing vehicle tipping back on to its rear supporting leg or legs as the rollers emerge from the coupling and ride up the jaw 9. In the event of the trailing vehicle being so loaded that it tips forward instead of backwards, the forward end of the draw-bar 8 will be depressed, and on the catch 11 being released and the tractor vehicle moving away from the trailing vehicle, projections 22 on the draw-bar will enter slots 23 in the wall of the box and so prevent separation of the draw-bar and coupling until the load has been properly adjusted. (*Sealed.*)

PRINTING AND ALLIED MACHINERY.

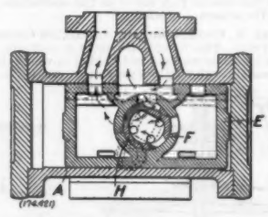
173,850. R. W. Crabtree and Sons, Limited, Leeds, and E. W. Smith, Edinburgh. Web Printing Machines. (2 *Figs.*) October 5, 1920.—This invention relates to web printing machines, and has for its object to provide simple and automatically operating means for the side lay adjustment of reels from which the webs are fed in such machines. According to the invention, the web on its passage from the reel to the printing couples, is passed over spindle *a*, which is freely movable longitudinally in both directions and is moved positively by the web on any lateral



deviation of the web to the one side or the other, and means are provided by which this lateral movement of the spindle is communicated mechanically to a two-way clutch a^1, a^2 mounted upon a spindle continuously rotating by movement derived from the web in its passage into the machine or from the driving gear of the machine, whereby movement is imparted to the usual screw side lay adjusting mechanism, so that thus the web reel may be moved laterally in one direction or the other and so to restore the web to its normal path. (*Sealed.*)

STEAM ENGINES, BOILERS, EVAPORATORS, &c.

174,421. J. Samuel White and Co., Limited, East Cowes, and A. Forster, Cowes. Distributing Valves. (4 *Figs.*) October 21, 1921.—This invention relates to distributing valves of the compound type for steam engines such as are usually employed in connection with auxiliary engines. According to this invention, a balanced reciprocating steam-actuated main valve carries a balanced auxiliary within it, the axis of the two valves being at right angles, and the auxiliary valve being adapted both to reciprocate within the main valve and to oscillate. In the preferred construction, the main valve E is of the shuttle type and comprises a cylindrical member having a piston face at either end and provided with ports which control the main steam ports formed in a cylindrical bore in the steam chest A within which the main valve is reciprocated. Formed within the



main valve E at right angles to its longitudinal axis is a ported cylindrical bore F within which works the auxiliary valve H. The auxiliary valve comprises a hollow ported cylindrical member which is mechanically reciprocated within its bore in the main valve, and is also oscillated about its own axis by the reciprocation of the main valve. The auxiliary valve controls the supply of steam which effects the reciprocation of the main valve and co-operates with the main valve in controlling the admission of steam to the main ports. As the live steam first enters the interior of the cylindrical auxiliary valve and thence passes to the interior of the cylindrical main valve, it will be seen that both these valves are balanced and not subject to unequal pressure and consequent wear, while, further, the manufacture of the steam chest and its valves is greatly simplified and its assembly facilitated. (*Sealed.*)